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INDUSTRIAL FILTRATION

BY

ARTHUR WRIGHT, M.E.

VOLUME I

THE MODERN LIBRARY OF CHEMICAL ENGINEERING

BOOK DEPARTMENT

The CHEMICAL CATALOG COMPANY, *Inc.*

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The MODERN LIBRARY *of* CHEMICAL ENGINEERING

So rapid has been the development of the technology of chemical processes during the past decade it is only natural that literature on the subject has failed to keep pace.

Those in a position to write authoritative books have been too busy solving practical problems to chronicle their experiences for others, and the feeling that chemical engineering data were still coming in at a rapid rate caused many to hesitate to publish data which might soon be rendered out of date by further advances in practice.

During the past two years, however, it has become generally recognized that the best interests of the industry and the profession demand a literature dealing with the fundamental processes of chemical engineering, not only as a basis for future progress but as an economical factor in current operation, as well as for the instruction of the younger men entering the profession.

Such a literature Germany has long had, and any American who has worked or studied in Germany knows what a great factor it has been in Germany's chemical development. It is not believed, however, that any good purpose could be served by a general translation of the German books, as much of the equipment discussed therein never has been and never will be used in this country. As a matter of fact, much of this German literature is now out of date, not only in this country but abroad, and in many instances our technical knowledge of chemical processes outstrips the world.

In view of these conditions, The Chemical Catalog Company has undertaken the work of interesting experts of indisputable standing in their several lines, in writing a series of technological works dealing with such fundamental processes in chemical engineering as Evaporation, Filtration, Distillation, Heat Transfer, Drying, Transportation of Liquids, Compression of Gases, Mechanical Handling of Materials, Grinding, Pulverizing, etc.

The scope of this Series naturally cannot be fixed at this time, but

books in this group, to be known as the "Modern Library of Chemical Engineering," will develop as chemical engineering knowledge develops. An effort will be made to drag forth facts and little tricks of the trade from their hiding places so that the current status of all the fundamental subdivisions of chemical engineering can be presented without reserve. Where this is not possible through the agency of a single author or group of authors, the co-operation of all the owners of facts will be sought to that end, and an editor or board of editors will be appointed to handle existing data with fairness to all.

The Modern Library of Chemical Engineering series will be uniform in format and binding. Some of the subjects with their authors, in addition to this volume on "Industrial Filtration" by Arthur Wright, that have thus far been definitely decided upon are as follows:—

Heat Transfer and Evaporation
By W. L. Badger,

Theory and Practice of Evaporation
By A. L. Webre and C. S. Robinson,

Fractional Distillation
By E. H. Leslie and E. M. Baker.

Announcements regarding the progress of the Modern Library of Chemical Engineering will be made from time to time, and of course more detailed information will be furnished at any time upon request. The publishers will welcome suggestions that will help improve the service these books on the technology of chemical processes are expected to render to chemical engineers, plant operatives, research men and students.

The CHEMICAL CATALOG COMPANY, *Inc.*

PREFACE

In chemical engineering, the industrial practice of filtration occurs so frequently that it must be considered a distinct department, and the subject of a volume by itself in any series attempting to cover chemical engineering at all completely.

This has been written as that volume in such a series, in an endeavor to make it a handbook useful to plant chemists and engineers, to superintendents, foremen and operators. It may also act as a textbook for students and cadet engineers, comparing for them the various designs of filters. Lay language has been used so that plant managers and purchasing agents, reading it as laymen, may better understand how to select the special filter for their particular duty.

This book sets on record some results of the author's own twelve years' filter experience, and there is therefore no bibliography to append.

Every effort has been made to keep the book practical, so that even Part I, "Theory of Filtration," is largely an accumulation of "tricks of the trade." Some new ideas are presented so that there is novelty in the work, which otherwise is made up of an exposition of standard practice. Such an idea, for instance, as the use of "muddied" wash-water ought alone to better many installations. Elimination of deep technical discussion has been premeditated in the belief that special papers before societies, or even a separate work, is a better means of treating this phase of filtration.

A brief explanation of the general plan of the book may be welcome here so that the reader can quickly get a bird's-eye view of the contents of the whole volume before entering its details.

To make the mass of technical data easy to read and understand, outline form is adhered to as far as practicable throughout. The Table of Contents gives at a glance the general arrangement of the entire subject matter, showing classification of subordinate material. Each chapter then follows definite outline form in turn, so that, in review, a summary and digest can be readily made.

In Part I, "Theory of Filtration," it is shown that as step follows step

in plant practice, certain laws of filtration become apparent. Application of these laws through certain mechanics, as set down in Part II, "Mechanics of Filtration" leads to the development of better "Filter Practice" which is the subject of Part III and the theme of the whole book. Concisely, the book's aim is to add a step to filter progress, and this is attempted in two ways:

(1) primarily by emphasizing the importance of mastering the fundamental laws underlying filtration and applying them in various ways.

(2) by analysis of filter development through criticism of representative types of machines as a key to future progress.

For purposes of ready comparison, each filter description in turn is reduced to a similar outline showing its development, operation, and drawbacks, and the advantages which explain its basis of application to certain work. Discussion of the drawbacks of each filter is included, not in the spirit of commercial criticism of patent features, but because it is plain that no one filter is applicable to all fields, and unless the limitations of each are understood, wrong selections may be made. In filters applicable to the same field, it is only by impartially balancing the merits and defects of each that decision as to the particular machine best adapted for the particular duty can be determined. By knowing the weakness of each, better appreciation of the advantages is gained.

Acknowledgment is made to the filter manufacturers for help in furnishing data, cuts, etc., which made the assembling of this material easier for the writer and more valuable to the reader.

Criticisms from filter manufacturers and filter purchasers are invited in the hope that their suggestions can improve future editions of this book and further the cause of better filtration.

Effort has been made here to help in the advance from rule of thumb methods, in the conviction that progress in the art would have been faster if the fundamental laws of filtration had been more firmly impressed long ago. This, then, is first emphasized; and, secondly, stress is laid on the need for wider filter knowledge among operators. Advance must be made through an educational campaign, since filtration generally has remained a little appreciated art. It is desirable that the young graduate engineer be acquainted with present-day filter practice, and it is still more desirable that practical plant men understand what can be achieved so that they will not too easily rest content with the operation of their own filters.

That they may find this profitable reading, and from it gain an appreciation of the art that will make them more critical of filters and filter operation, is the wish of the writer,

ARTHUR WRIGHT, M.E.
April, 1923.

The MODERN LIBRARY *of* CHEMICAL ENGINEERING

In addition to the present volume on "Industrial Filtration" by Arthur Wright, the following books are included in this Series:—

Heat Transfer and Evaporation
By W. L. Badger,

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Fractional Distillation
By E. H. Leslie and E. M. Baker.

Other books to be included in the Series, which is briefly described in the preceding pages, will be announced from time to time. Among the subjects to be treated are Drying, Transportation of Liquids, Mechanical Handling of Materials, Compression of Gases, Electric Heat (Its Application to Industrial Processes), Grinding and Pulverizing.

CONTENTS

PART III

Filter Practice

FUNCTIONS OF INDUSTRIAL FILTERS.

FUNCTIONS OF INDUSTRIAL FILTERS.

Filtration Defined.

Filtration, i.e., "separation of solids in suspensions from a liquid vehicle," has an important industrial function, for clarification plays a part in the majority of chemical operations, and the uses to which filters can be applied are increasing at a high rate.

To begin with, the difference must be defined here between *industrial filters* and other filters (such as: municipal water filters; boiler-feed-water filters; filters for recovery of machine oil and the separation of water from gasoline; household drinking water filters, etc.), for it is the *industrial filter* only that is our particular subject. This is the filter that is used for chemical engineering. The chief difference between industrial and other filters is this: the industrial filter handles a large volume of solids in a relatively small volume of liquid, and is equipped to recover the solid and discharge it in a semi-dry state. Other filters generally handle large volumes of liquid with small solid content, these solids being measured in grains per gallon as against the industrial's pounds per gallon and tons per hour. The solids in these other filters are disposed of as mere muddy back-wash.

The function of the industrial filter is to put laboratory precipitate-filtering into large-scale commercial practice. In the laboratory, precipitates are filtered through filter paper in funnels. In industry, the filtering is done by various types of machines which will be discussed later. In laboratory work, pure reagents are used and the precipitates to be filtered are formed according to chemical formulae. In commercial practice, however, the reagents, purchased in bulk, are often far from pure and must themselves be clarified of extraneous matter before they can be used to throw down the precipitate which is to be recovered as a commercial product. The industrial filter may thus play two parts in one process.

An idea of the extensive use of the industrial filter may be realized by running over only a few of the industries in which the filter functions, as for instance:

- chemical and dye works,
- food product plants (i.e., corn syrup, starch, cane and beet sugar manufacture, etc.),
- paper manufacture,
- pottery works,
- oil refineries,
- mining and metallurgical mills,
- municipal sewage disposal plants,
- etc., etc.

There are, of course, obvious applications for industrial filters, but the advance made in filter design and operation has opened up new uses such as:

> leaching solubles from ores, organic matter, etc.,
> conditioning solids to be dried,
> agglomerating dusting materials,

and other work not essentially filtration in the sense of its popular definition as "separating solids from liquids."

Industrial filtration is "a lowly art," for many years governed only by rule-of-thumb methods. But, with the introduction of the modern filter, we are beginning to recognize that there are fundamental principles underlying their best operation. Filtration is no longer summed up in the old adage "get a good hard cake," but comprises, in addition to clarification of the liquor, the complete washing of the soluble from the deposited solids; the drying of the cake; thorough discharge of the cake so that the filter medium is maintained in a free-filtering condition for recurring runs, and a consideration of pumps, filter cloths and other auxiliaries. It is only when these principles are understood and applied that the filter station reaches its true economy and efficiency. These underlying principles, therefore, will be discussed in detail under these separate headings:

1. Clarification
2. Cake Building
3. Cake Washing
4. Cake Drying
5. Cake Discharge
6. Filter Media
7. Theory of Filter Application
8. Auxiliary Equipment.

The different makes of machines will be described fully and individually under the heading "Mechanics of Filters" but it is well to have clearly defined at the beginning the general types of filters in order to avoid confusion by references thereto in earlier discussions. Filters may be divided into classes as follows:

1. Plate and Frame (or "chamber") filter presses
2. Leaf filters (both vacuum and pressure)
3. Continuous filters (both rotary drum and rotary leaf)
4. Special filters (bed filters, etc.)

To illustrate the difference between chamber and leaf filters, "suppose that we have to clarify a muddy liquid with no other means than a bag, a piece of pipe and a string. We may then proceed, after inserting the pipe into the bag and fastening the bag to the pipe, in either of two ways:

> (1). We may pour the muddy liquid into the bag, catch the mud *inside* the bag and the clarified liquid in a receptacle below, or—

(2). We may distend the bag with any convenient means to prevent it from collapsing, submerge the bag into the muddy liquid and draw the filtrate from the pipe. In this case the mud deposits on the *outside* of the bag."

The first case illustrates the principle of the chamber press, the chamber being the bag. The second illustrates the principle of the leaf filter, the bag in this instance being the leaf.

Plate and Frame Filter Presses.

These consist of a series of enclosed chambers into which the muddy liquid is pumped. The walls of these chambers are made of filter cloth hung on solid corrugated plates and the liquid, filtering through this cloth, is drained off while the solids are deposited inside the chambers. These chambers are made up of alternate cloth-covered plates and spacers (or "frames") clamped together.

Leaf Filters.

These consist of a series of non-collapsible bags (called leaves) inserted in a tank which is open for vacuum leaf filters and closed for pressure leaf filters. In vacuum leaf filters the liquid is sucked into the leaf; in the pressure type it is forced into the leaf by pump pressure. In either case, the solids are deposited upon the *outside* of the leaf.

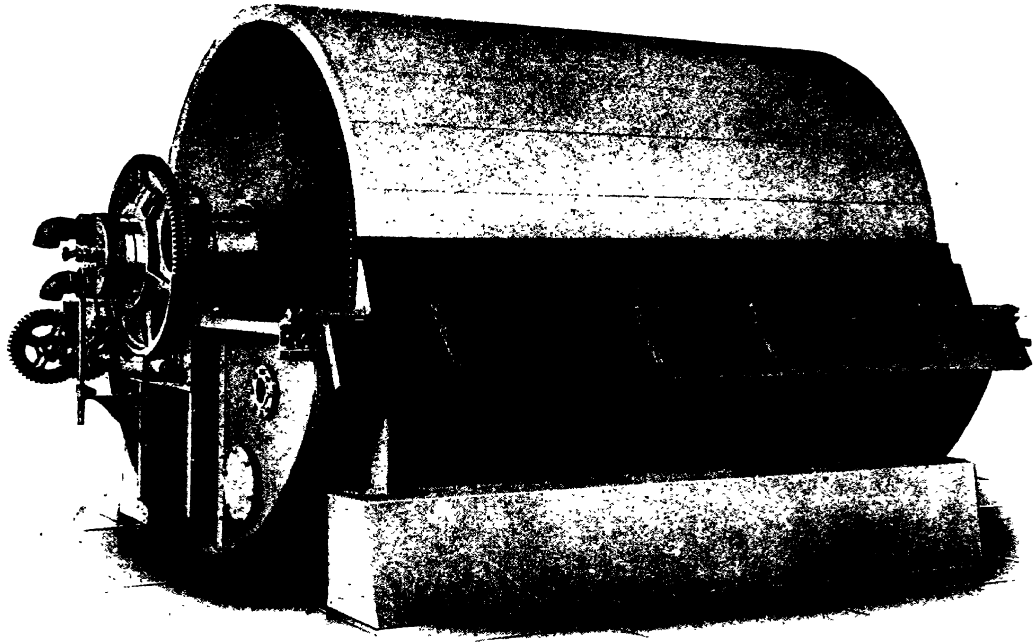
A mark of distinction between leaf and chamber presses is their difference in discharge. In chamber presses, the chambers are opened and the deposit, or cake, is removed by hand. In leaf filters a reverse current of steam or compressed air blows the cake loose from the leaf automatically and hand labor is eliminated. Leaf filters may be discharged when the cake is of any thickness, but plate and frame presses are discharged only when each chamber is built up solid with cake.

Continuous Filters.

Continuous filters are developments of leaf filters and are of two types, —(1) drum, and (2) sectionated rotable leaf.

Continuous Rotary Drum Filters.—A rotating drum covered on its periphery with filter cloth is partly submerged in a tank of muddy liquor. The filter cloth is divided into parallel sections. On each section a separate cake is formed by separate vacuum pipes which draw off the filtrate while the drum revolves through the liquor. As the drum rotates, the cake is lifted from the tank and before it turns over to a point where it would again enter the liquor, the vacuum is shut off, section by section, allowing the cake to be removed from the drum and leaving the cloth clear for a new cake to be built upon it by return of vacuum. This filter is therefore clarifying the liquid by building up and discharging the cake in a continuous cycle.

Continuous Rotary Leaf Filters.—This type of filter consists of a series of circular leaves rotating on a central shaft. Each leaf is divided



Courtesy Oliver Continuous Filter Company

FIG. 1.—A Most Popular Modern Filter
Oliver Continuous Filter—Rotary Drum Type.

into perhaps 10 sectors and each sector acts as an individual leaf in itself, being equipped with its own vacuum outlet at the center. As these leaves rotate in the tank they are partly submerged in a tank of muddy liquor and the cakes, formed by the vacuum, are deposited upon the face of the leaves. The cakes are discharged by reverse air current supplanting the vacuum just prior to the point of submergence in the cycle.

The marked difference between rotary drum filters and rotary disk filters is that the filter area in the first is distributed *around* the shaft on the periphery of the drum, while in the other it is the surface of the disk on both sides of each leaf, at *right angles* to the shaft. The principle of operation and discharge is identical in both.

Bed Filters.

Bed filters are horizontal filtering surfaces consisting of crushed stone or gravel topped with sand or filter cloths laid on false bottoms. These filters are largely confined to work with acids and are operated either by gravity or suction. Discharge is effected by removing a screen or other stripping member which lifts the cake from the bed.

The art of filtration is chiefly a summary of "tricks of the trade," but industrial filtration is a branch of chemical engineering unique in the number and importance of small factors, or constants. This fact has been borne out many times when failure to make a filter develop desired capacity has been changed to complete success by so small a factor as ten degrees difference in temperature, or 15 per cent added solids of suspension. Emphasis on this is made here as a caution against hoping that we may develop formulae of general value. Any formulae for practical use cannot be overladen with constants, and without these constants no filtration formula is applicable, except in a few isolated cases. Obviously, such formulae are not worth the work necessary for their development.

Machines and methods herein described are those developed in the United States, since our subject is *American* Industrial Filtration.

PART I.

THEORY OF FILTRATION.

Chapter I.

Clarification.

In all chemical engineering there is probably no branch that combines so intimately the functions of the chemist and the engineer as does filtration.

The quantities to be filtered in most cases are measured in tons, so that the *engineer* has much for his attention in respect to handling these materials. The filter is the main unit in filtration practice, but tanks equipped with agitators for mixing the material for the filter; pipe lines and pumps for introducing the mixed material into the filter; pumps for developing filtering force, whether it be pressure or vacuum; receivers for clarified material and its conduction to the next process, etc., are all strictly in the engineer's domain.

Proper precipitation of the solids of suspension; control of the temperature at which the precipitation takes place; specifying the density at which the material must be handled; prescribing the corrosive content and nature of the liquid, together with the allowable materials of construction and other similar points, are all distinctly in the *chemist's* province.

Of these two divisions, *the part played by the chemist is the most important*. It is for this reason that the following chapters on the Theory of Filtration appear before those on the Mechanics of Filtration, in order to give the control chemist a better insight into the peculiarities of filtration so that he can handle his material most economically.

By utilizing a combination of the various phases of filtration (for example: combining uniform-cake-building with displacement-washing; or, limited-cake-building with drying) filters are applicable today where hitherto they could not be considered. In this it is seen how application of the theory of filtration results in progress and development of its mechanical features. It is therefore hoped that better acquaintance with the Theory of Filtration will develop more field of applications for these machines.

Definition.

Clarity of filtrate is, in the vast majority of cases, the primary object of the filter, but, as will be shown later, it is too often over-emphasized. When absolute clarity is not required, a different attack than that which will be outlined here is often possible.

The number of cases where capillary attraction and adsorptive action

are real factors in clarification are relatively so few and far between that this general law can be defined:

> *Clarity of filtration is due to superlative straining of the particles of suspension from the liquid in which they are suspended.*

This statement will doubtless call for criticism from some quarters, but it is held to be basic by reason of success obtained in handling a large number of problems completely ignoring capillary and adsorptive actions and concentrating solely on straining.

Open Woven Fabrics.

The choice of straining or filter mediums determines the nature of the straining or filtering. It is the popular belief that woven fabrics effect clarification by surface filtration, i.e., that the solids are caught on the surface of the fabric and build up to form a cake. Such a belief is rational when comparing a woven fabric with a granular bed filter medium. It is obvious that any particle penetrating the surface of a sand bed has opportunity to be caught in the interior of the bed before issuing from the false bottom as a cloudy filtrate. Both theories are, however, subject to liberal interpretation, for we have only to witness the number of times the filter cloth is clogged and not opened even though the surface be hand-cleaned with vigorous scrubbing and the cloth given reverse washings. Or, again, to watch the working of boiler feed-water filters wherein the initial flow is not clear and after running clear can be run for a period only before the filter must be cleaned.

The answers are obvious. In the former, solids penetrate the cloth and are held firmly in the meshes of the cloth,—surely not true surface filtration. In the second case, clarification begins only when the retained solids form of themselves a filter medium on the top of the sand bed. The reason that the rate of flow is approximately constant in sand filters is because the deposit on the bed, as it builds up, has the effect of building up a resistance to the flow which increases the filter pressure. At some point this pressure builds up sufficiently to force the deposit through the surface of the sand bed and to work into the interior. Manifestly, if the filter is run long enough, the solids will issue through with the filtrate. In point of fact, therefore, the initial filtration through fabrics approximates filtration through-a-depth and with sand beds true clarification commences with surface filtration.

Until recently, the practice was to choose a densely woven filter cloth so that none of the solids could pass through it. This disregarded the principle that *the initial coating or film, not the fabric itself, is the true filter medium.*

With the above principle in mind, we have ground for the contention that too many industrial filters are still equipped with too dense a filter cloth. Mechanical wear will often dictate the choice of a heavy cloth,

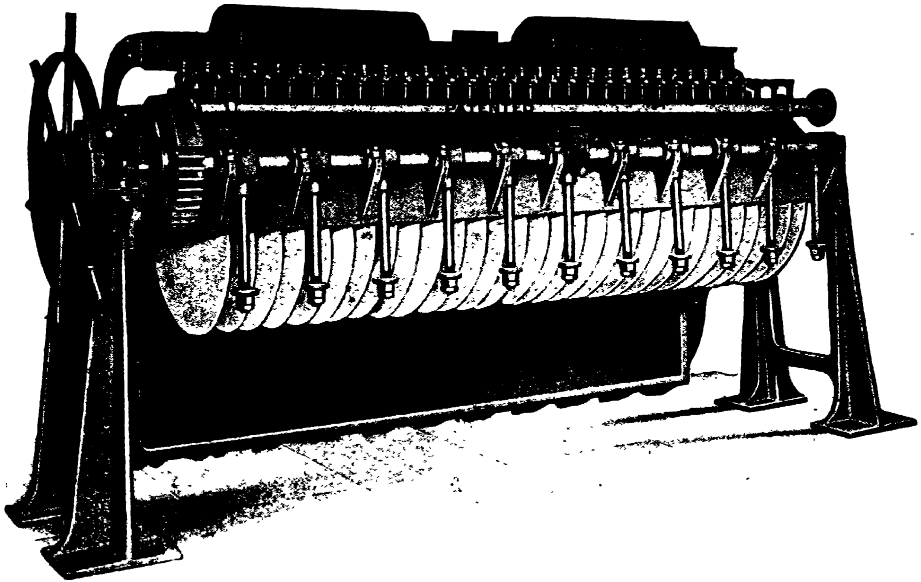
but this should not be the signal to use a dense cloth. It cannot be expected that with the use of open cloths the initial clarity will be satisfactory, but it will be found that there is no hardship in refiltering the first runnings. Usually the filtrate brightens up readily and the amount to be returned can be added to the feed of the filter or else run through a separate filter which is used as a "polisher." Local conditions will govern the best means of handling this cloudy filtrate. It is not practical to equip filters with a more open cloth or a thinner fabric and not provide for the handling of cloudy filtrate. Absolute clarity can sometimes be obtained with such cloths by working with a low initial pressure, as for instance, gravity feed. There are cases where this is good practice, but as a general rule it is precarious, for it is required only that an insufficient deposit be made on the cloth when the pressure line is opened and the solids will be pushed through into the filtrate. The basic idea is that clarification shall be effected by virtue of the deposit of the solids on the filter cloth rather than that the cloth shall be the real medium. If this be carried out, it will be found that those particles that clog the dense cloth pass through into the filtrate so that the open cloth is maintained in a free filtering condition for recurring runs. This, of course, is obvious and need not be elaborated upon save to consider further the kind of cloth to use.

What is true about providing for cloudy filtrate when using cotton filter cloths is even more important when using metallic cloths. These fabrics are designed as permanent mediums, and their initial cost is justified only by their long life. Consequently, how much more fatal it is to allow these cloths to clog up! Users are the best judges of the delays and trials when caustic, acid, and heat treatments are resorted to in order to regain their porosity. So much of this is needless if only provision be made to take care of cloudy filtrate and *an open weave of uniform mesh be used.*

Unsatisfactory Use of Double Plies.

It must be borne in mind that cotton is a cellulose product and with very few exceptions swells when immersed in liquids. Consequently, weaves that seem quite porous before wetting are quite dense afterward, and, similarly, loosely woven fabrics that often seem flimsy when cut upon the table will prove quite substantial in practice. Many investigators have been impressed with the excellence of thin muslins, but have been deterred in their use by reason of their frailty. Such mediums are, indeed, very efficient, for they effect the nearest approach to instant surface filtration and, by reason of the thin yarn from which they are woven, do not clog up if their surface be cleaned,—for they have not enough thickness to hold solids.

The writer has seen installations of thin cloths strengthened by using two layers. This is usually a poor expedient, for the idea that the inner cloth backs up any rent or tear in the outer cloth is not well founded. To obtain this result, the two layers should be made integral one with



Courtesy United Filters Corporation

FIG. 2.—A Long Popular Modern Filter.
Sweetland Filter—Pressure Leaf Type.

the other by close lateral stitching or by spot pinning, etc. Then the possibility of a wrinkle occurring in the inner cloth at a point where the outer cloth is torn, is decreased, but this procedure has the same effect as the use of heavy cloth to begin with, and there is certainly no advantage in the scheme worth the effort. To prove the futility of double thickness of thin muslin, one has but to inspect a filter so equipped that has been in operation a few days and note the accumulation of cake that occurs at the bottom of the leaves or plates. This increases with every run and is accounted for by the fact that the outer cloths are ripped or have "pin" holes, so that the under cloth must do the filtering at such points. More cake builds up than can clear through the hole when the filter is discharged, and this excess works down to the low point of the leaves.

Satisfactory Fabric Reinforcement.

The idea of reinforcing the muslin, to strengthen it, is good, but the under cloth must be of an excessively open weave such as a "hose duck," burlap, cocoa matting, or the like. Then, any solids penetrating the muslin will issue from the leaves as cloudy filtrate. It is amazing to see the extent to which muslin can be torn and still give good service under such conditions. The length of life of muslin is then made positively practical even when using those machines that require the cloths to be sewn to the leaf. Diverse opinions have been rendered on this subject, but the writer was much impressed with the working of a battery of Sweetland filters having an aggregate filter area of over 7,000 sq. ft., where, after a thorough investigation was made of this point by several months' experimentation, muslin backed up by burlap was used. The life of this muslin was doubled, the output increased and material economies were effected.

Importance of Agitation of Liquor in the Filter.

Use of open weaves is less necessary in filtering crystalline solids because these particles are large, and, as there are no fine particles to be caught in the meshes, a dense cloth used for crystals can easily be kept in a free filtering condition. This holds true except when such liquors also contain fine impurities in suspension, the nature of which is not crystalline. In such cases the above is of positive importance.

A case occurred in a plant where calcium sulphate was thrown down from an acid liquor, but a considerable percentage of flocculent precipitates were present as well. The superintendent and chemist were advised of the advantage of using open cloths, and tried them. They reported utter failure: the clarity never did become brilliant. One glance at their cakes, as discharged from the filter, told the whole story. As every filter manufacturer warns against the formation of tapering cakes, they were informed on this point. They were not troubled with poor washing; had no difficulty in discharging; and the leaves were not warped excessively. But,—they were not equipped for *thorough agitation of the*

liquor in the filter. Consequently, the heavy solids sank to the bottom and, with their open cloths, the upper part of the leaves received only the lighter solids which were fine enough to penetrate the filter cloth without coating the surface with a substantial deposit. The solution of the problem lay in maintaining a steady agitation of the liquor in the filter to prevent settling of the heavier solids and thus assure uniform cake thickness. This resulted in clarity of filtrate. This instance shows the relation of agitation to clarity and also illustrates what small factors can often be the deciding point between success and failure in the art of filtration.

Filter-Aids.

It has been explained that initial coating or film of the deposited solid, not the fabric itself, is the true filter medium. To aid in this coating, some additional coating material is often added to the liquor, the material being termed "filter-aid." A filter-aid, whether it be waste industrial matter (such as sawdust flour; calcium sulphate; calcium carbonate; pulverized bone-black) or some specific filter-aid product on the market such as "filter-cel," must have three main properties: (1) its specific gravity must be such that when mixed in water, or in the liquid being filtered, it will stay in suspension without settling or floating; (2) it must be of a free filtering character; and (3) its chemical composition must be inert or harmless to the liquid. Filter-acids as *clarification agents* will be discussed here, and their use in increasing capacity, facilitating discharge, etc., will be taken up later.

Pre-Coating the Cloths.

The fundamental use of a filter-aid as a clarification agent is in producing an auxiliary filter medium upon the filter cloth by means of "pre-coating." Pre-coating is the term used to define the initial filtration of a filter-aid before opening the main liquor line. This filtration is generally only for a minute or so, and it is sufficient when the effluent issuing from the filter is brilliant. Too often, the impression seems to be that this coating must be of some sensible thickness,—1/8 in. or 1/16 in.,—where, in fact, a mere film is sufficient. On raw sugar liquors it is practical to pre-coat the cloths, using 1 lb. of "filter-cel" per 100 sq. ft. of filter surface, and on examination of a filter leaf after coating it will seem to be without any deposit, but the clarity of the filtrate will be found to be brilliant when filtering the sugar liquor, and a white surface will be noted on the inner face of the cake when discharged. This is probably the minimum amount to use and safer results are obtained by doubling this amount, but even this will give a coating difficult to measure and no liquors have been encountered to date that will not give a brilliant filtrate through it. Obviously, more than this is an extravagant use of the material and unnecessarily increases the initial resistance of the medium. Pre-coating is an automatic operation in the sense that the uniformity of the coating takes care of itself and the time required is

seldom more than a small fraction safely put at 10 per cent of the total cycle. Therefore, a filter with anything over 11 per cent excess capacity is sufficiently large to meet production. This amount, however, may be called the maximum, for the time required depends on the method used for pre-coating.

Methods of Pre-Coating.

The vehicle to use for this pre-coating is a matter for local decision, but there are three methods in practical use giving eminent satisfaction.

(1) A slurry is made up of filter-aid and water (or, when handling varnishes, etc., some solvent), and this is filtered in the usual manner, shutting off when the filtrate is brilliant. In most machines the amount of unfiltered slurry demands its withdrawal from the filter before admitting the sludge. Best practice, therefore, is to locate the slurry mixing-tank below the filter so that the excess unfiltered in the machine may be drained back, using the minimum air pressure to hold the coating on the cloths.

(2) To obviate this draining back, some plants use the second method, where clarified effluent is used instead of water or the solvent and sufficient filter-aid is added to insure a pre-coat when the following operation is carried out: the pre-coating liquor is admitted to the filter until full, when the regular liquor is fed to the machine. The lay-out for this method is usually to locate the pre-coating tank above the filter so that no pump is necessary to feed the pre-coating slurry to the filter, gravity-feed, with large pipe lines being sufficient. In this case the excess slurry is not withdrawn, but filters through the machine more quickly than the time required to drain the excess and refill the filter. This is probably the most fool-proof method of pre-coating. The deposit is a clean coating of the filter-aid, and there is required no such nicety of control in maintaining positive pressure within the filter as in the case of the first method, and, further, the drainage members and outlets of the filter are not filled with a water liquor but with a high strength filtrate. The one canal for the return of cloudy filtrate (which must be provided even if pre-coating were not used) takes care of the first filtrate.

(3) The third method is that used extensively in sugar refineries of the United States and Canada, and is considered by many as the most practical. Here the solids of suspension in the liquors to be clarified are present in relatively low percentages and it is found quite practical simply to add sufficient filter-aid to the unfiltered material so that the volume of the filter-aid far exceeds the original solids. This liquor may then be fed as in the second method. The coating will be found to be such a close approximation to straight filter-aid that the practical results are the same. Theoretically there is much to commend this system, but the human element in its control is its weakness, for too often an operator, falling behind in his schedule, will prolong the time of pre-coating and thereby increase his output of clear filtrate at the expense of excess use of filter-aid. Wherever the quantity of filter-aid used is an item of operating expense, the second method of pre-coating proves to be the

most economical, for there the operator has no incentive to prolong the pre-coating cycle and obtain a filtrate which he has previously clarified.

Modifications in these methods of pre-coating are found in special instances. An example is seen in the handling of cachazza, or the settled solids in raw cane sugar manufacture, where the semi-clear supernatant liquor from the settling tanks is a practical vehicle for the filter-aid in the pre-coating operation. Some chemical plants use the wash filtrate for this purpose, and when the quantity of wash-water is small, permit its entire evaporation. This is good practice, especially when the strong liquor is a viscous material.

Considerable educational work was necessary at first to popularize the use of pre-coating, but industrial plants now generally accept the principle as a part of their routine. It is now held that the scheme is applicable even to municipal work with sand filters, as the following experiment would seem to indicate.

During the war, when sulphuric acid was at a premium, a celluloid works contracted for a quantity of 98% sulphuric acid. This had to be crystal clear, and in the mixing of oleum and 66° Baumé acid to get this strength, fine colloidal lead and iron sulphate precipitated. It required an average of thirty days for a batch to settle so that a clear supernatant liquid could be drawn off. This delay of course increased the cost, and efforts were made to filter the liquid. The filter medium practical for acid of such strength was limited practically to silica as sand, "filtros," carborundum, alundum, etc. It was hoped that one of these materials could be made dense enough to clarify the colloids from the acid and not clog up after a couple of runs. The manufacturers of these media worked hard to meet the requirements, but without success. Pre-coating was suggested and a sample of acid secured for a laboratory test. It was planned to run this on a Buchner funnel using an alundum plate as the medium. The right size plate was not at hand so a sand filter was approximated by filling the bottom of the Buchner with gravel and then covering with ordinary beach sand. A mixture of clear 66° acid and calcined filter-cel was poured on the sand and a small suction filtered off the acid. The filter-cel most effectively clarified the 98% acid then poured on the bed. The thing of most interest was that the filtration was a close approximation to true surface filtration, for the sand bed, after the coating was removed, was to all appearances as clean as when laid in the filter. This is significant, for in sand filters true clarification starts when a deposit coats the surface of the bed. Hastening this coating is a move toward progress in sand filtration.

Pre-coating has already increased the fields of application to include those liquors hitherto thought inapplicable, and has played a big part in advancing the use of open filter cloths. With the principle of pre-coating defined and endorsed, it is a matter of local consideration and research to determine the best material to be used. Standard filter-aids (such as filter-cel) are almost universal media, but often a better medium can be obtained free from the property of imparting taste to food-product liquors, or free from sliming up (as silicates in handling caustics). Wood

pulp is a substitute in the first case, and waste calcium sulphate from phosphoric, tartaric acid, or similar manufacture answers well in the second case.

Colloidal Clarification.

The most interesting of the more difficult clarification problems is the filtering of colloidal solids of suspension. Filter men use the term "colloid" very comprehensively and often extravagantly, to make it include solids whose size and behavior are not those of true colloids, but whose filtering characteristics are. From a filtering standpoint, any solid so fine, or any flocculent precipitate so weak in structure as to make true clarity difficult to obtain (or, when obtained, difficult to maintain economically its rate of flow), is put in the colloid class. Examples are, roughly: cane sugar liquors as found in plantation and refinery practice; raw sewage; soaps in the neutralization of free fatty acids in vegetable oils; and aluminum hydrates precipitated from the introduction of alum as in municipal water clarification.

Obviously, the prime difficulty in colloidal clarification rises from the delayed arching effect of the fine solids in deposit, and their easy breakdown under pressure. Any filter fabric must be perfectly and *tightly woven* to obtain clear filtrate from these materials. But we have previously pointed out that use of tightly woven fabrics is objectionable practice, not to be resorted to when it is possible to handle the filtrate through open weaves. Then, how can open media be used for colloids? The answer is: By the addition of filter-aid.

In most industrial liquors containing colloidal suspensions, the filtrate is of far greater value than the solids. When the solids have by-product value, there is enough gained to warrant the recovery of the solids to be considered as a separate problem apart from the work of filtering the liquors. An example of this is seen in vegetable oil refining. In this, the neutralized free fatty acids were formerly recovered as soap stocks by the process of *sedimentation.* They are now recovered more advantageously by the Baskerville Process through *filtration.* In this process, cotton linters are added to facilitate filtration of the neutralized acids, and the recovered solids, spoiled by the linters for use as soap stocks, are recovered as baser material. These filtered solids are then taken and the free fatty acids reformed by acidulation which makes the recovery of the grease a simple process, since the grease floats on top of the acidulating liquor making it easily recoverable by skimming or by high speed centrifuges of the cream-separator type. Thus, the soap stock is finally recovered. This process clarifies by filtration instead of by the old method of sedimentation and has these advantages: it saves time, as sedimentation is slow; it assures positive clarification in place of uncertain clarity, it leaves less of the valuable refined oil behind in the waste product, and it requires far less tankage. Plainly, then, filtering here is a better method than sedimentation. The secret of filter success in this process lies in the addition of the cotton linters, which is, in effect, the addition of filter-aid.

Formerly, filter paper and paper pulp filters (the first consisting of sheets laid upon filter cloth in plate and frame presses; the second being made of circular blocks with internal drainage) were used because these media were denser than any cloth and so insured complete clarification. These were particularly used in breweries, in gum and varnish works, fruit juice plants, etc., because here the solids are so fine that they pass through cloth. Today, pre-coating the cloth with paper pulp or other filter-aid accomplishes the same end and does away with their use. This marks an advance in simplicity and economy of filter operation, for the use of filter paper and pulp blocks was difficult indeed. The sheets of paper had to be laid with extreme care to get them smoothly adjusted without tearing. The paper pulp blocks had to be washed after each run and then compressed back into shape under hydraulic presses. To-day, the filter-aid is simply added to the liquor and filtered, forming its own filter medium.

To sum up: Clarification is the department of industrial filtration which meets the popular definition of filtration,—*the separation of solids from liquids.*

Chapter II.

Cake Building.

In industrial filtration, the point of liveliest interest to the plant superintendent is the *capacity* of his filters.

Capacity is the amount of cake discharged or amount of filtrate obtained. It is directly proportional to the time required for the whole cycle of operation including cake forming, cake washing, cake drying and discharging, but it is primarily based upon the *Rate of Flow.* The term "Rate of Flow" covers not only the flow obtained per unit of time (as, for instance, the gallons per sq. ft. per minute), but, what is the same thing on a larger scale, the total flow per cycle.

Many ingenious efforts to increase capacity have been made which have failed because of incomplete comprehension of the principles that underlie cake-building. The importance of understanding these principles is strikingly shown in the experience of one superintendent who was not getting sufficient output from his three filters and was planning to install a fourth machine. By modifying his method of operation, however, two of his filters were made to deliver the quantity he expected of four, saving this extra installation altogether, and, moreover, leaving his third machine for extra output.

The factors which underlie cake-building and govern capacity may be outlined thus:

(1) cake density
  (a) initial pressure
  (b) concentration of solids
(2) steady, increasing pressure
(3) critical pressure
(4) economical limit
(5) homogeneity of feed
(6) temperature, viscosity and density of feed
(7) flocculation
(8) filter-aids
(9) maintenance of cloth porosity
(10) design of drainage member

1. Cake Density.

The Rate of Flow is proportional to the porosity of the medium for the passage of the filtrate. Anything that tends to reduce the openings tends to reduce the rate of flow. The depositing cake does this auto-

matically, and our consideration must center on those agents which unduly hasten this decrease in flow, i.e., (a) too high initial pressure, and (b) insufficient concentration of solids in the feed.

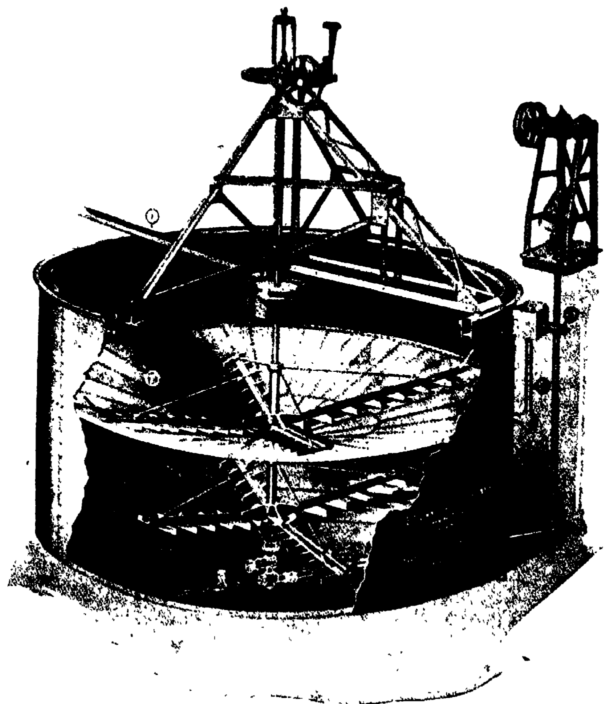
a. High Initial Pressure.—As a particle is deposited on the filter medium, liquid has passed through the medium. The solid particle has come to rest, the liquid maintains its motion, although possibly at a slower gait. The solid, prior to its deposit, was in motion, being carried by the liquid as its vehicle. Therefore, having been in motion and then coming to rest, it has an impact force and a compacting action upon the deposit already formed, or, if it is the initial flow, a forcing action trying to penetrate the pores of the filter cloth itself. By the law of mechanics for momentum, this force is in proportion to the mass weight of the particle (including its entrained liquid) and to the velocity of movement. The velocity is the factor for our consideration. The velocity is proportional to the pressure, according to the familiar law of hydraulics. Any filter, when first starting up, has its maximum velocity of flow, the decrease from which varies with the material in hand. In some cases this is gradual, in others the decrease in velocity is rapid. Rapid decrease defeats high production. The momentum of the first coating-solids is of prime importance. This rapid decrease is nothing more than the creation of high resistance to the continued flow, and a tightly packed cake is always more resistant than one loosely packed. Here, then, we see the importance of cake density. Decreasing the initial flow and consequently the velocity of the particles prior to their deposit, is the answer here. This is accomplished by low initial pressure. This substantiates the old adage: "Start the press with a low pressure." It must be pointed out that while this rule does not apply to free-filtering liquors (such as caustic soda carrying calcium carbonate in suspension, or calcium sulphate in phosphoric acid, etc.), it is vital in handling average liquors.

b. Concentration of Solids.—Cake density also depends upon concentration of solids in the liquor. If the liquor is high in solids, the cake deposited is more porous than a cake formed from a thinly concentrated liquor. This is because the rate of flow of thin liquor is greater and deposits the solids with more velocity, producing a denser cake. A tightly packed cake, as we have seen, is plainly more resistant than one loosely packed. The liquor should, therefore, be concentrated as much as possible in order to form a loose, porous cake which prolongs the period of good flow.

Decantation prior to filtration, to concentrate the solids, increases the capacity of the filter. This is universally true in regard to capacity of cake discharged, and there are instances where the rate of flow is also increased. Rate of flow is increased because the cake deposited from concentrated liquor is more porous, and thus allows freer passage for the liquid. There are a great many installations of Dorr Thickeners feeding the underflow discharge to continuous filters where contiguous filters could not have been used on the original unthickened slurry. The reason for this is that the accumulation of solids enables a cake that can

be discharged to be built on the filter whereas from a thin liquor so thin a cake is formed that discharge is impractical.

There are numerous cases where this procedure is especially economical and advantageous, but in the main it is confined to those materials that settle readily with a satisfactorily clear supernatant liquor. If, however, the supernatant liquor needs further clarification, then this pro-



Courtesy The Dorr Company

FIG. 3.—Widely Used Modern Clarifier.
Dorr Thickener—Continuous Settling Type.

cedure is really "two bites at a cherry" and has no advantage, for clarification of such decanted liquor, with its fine particles, is more difficult than filtering the original liquor, especially if the solids are waste products so that filter-aid may be added to the concentrate without chemically affecting the filtrate.

2. Steady, Increasing Pressure.

To increase capacity, the attack most often pursued is to increase the filtering pressure. This is logical, for the filter medium and the cake

can be considered multiple orifices, so that the law applies that: "the flow of liquid through an orifice is proportional to the pressure." It is becoming better recognized that a constant, or *steady* pressure is the most desirable for obtaining best rate of flow. Fluctuations in pressure produce an effect similar to that of tamping wet ground. The cakes are made denser and more resistant by this action. If efforts are made to form porous cakes at the start of operation, similar efforts must be made to maintain this porosity. One of the agents best calculated to defeat this endeavor is the hammer-like action of pulsating pumps. For this reason, slide valve and plunger type pumps are never supplied as new equipment, being supplanted by even-pressure machines. Fluctuating pressure produces irregular flow for the resistance produced by the high pressure is too great for the lower pressure to force the liquid through rapidly. This point is one of the favorable factors in the use of montejus and pneumatic eggs, gravity feed and vacuum receivers, etc.

Use of centrifugal pumps automatically insures low initial pressure, steady, and increasing pressure. Centrifugal pumps with rotors easily accessible and with sufficient clearance to allow the pumping of gritty and coarse materials are admirable in that the amount of pressure is in reverse proportion to the amount of filtrate flowing.

Increased *pressure* is identical with increased *suction* when operating vacuum filters. There have been misconceptions on the difference of pressure and vacuum filtration. Much discussion has arisen over the merit of "pushing" the liquid through the filter, as in pressure type machines, and "drawing" it through with vacuum filters. The action here is *not* analogous to the familiar law of mechanics that a cane can be *drawn* along a pavement more easily than it can be *pushed* along. The action in pressure and suction filters is identical: *the filtrate is pushed through in both instances,* the pump being the agent in one case, and atmospheric pressure the agent in the other. In other words, the filtering force in either case is the difference of pressure on the two sides of the medium, in the one case it being the pressure due to a pump or head greater then atmospheric pressure; in the other, that of the atmosphere compared to a pressure lower than atmospheric. In consequence, laws pertaining to pressure filtration apply also to vacuum filters. What is of advantage in vacuum filtration is its evenness and ease of control. The only fundamental difference in vacuum and pressure filtration is that the former is limited to atmospheric pressure as the maximum, while the limit of the latter is only the strength of the materials of construction. The range of difference in pressure is limited to 14.7 lb. per sq. in. as the theoretical maximum with the vacuum type.

3. Critical Pressure.

That an increase of pressure increases the quantity of filtrate is not universally true. It is practical with almost theoretical accuracy when handling solids of a crystalline or granular texture. It is true to a certain extent with every material, but with some only through a small

range of pressure. Those with the smallest limits are flocculent precipitates with which a few feet increased head of gravity feed is all that will increase the flow before a contrary result is obtained.

The reason that, in practice, the law of increased pressure does not always increase the flow, is found in the fact that in filtration the orifice (i.e., cake porosity) becomes a variable under pressure. For every material there is a pressure above which an increased flow is not obtained, but a decreased flow is had instead. This is known in filtration parlance as the *critical pressure* for that material.

Confusion sometimes occurs on this point, for an operator will, after filtering at a given pressure, jump his pressure up and point to the larger stream issuing from the filtrate outlet. Unfortunately for him, the flow does not last long. It is occasioned by the fact that the increased force compacts the cakes on the leaves and forces the entrained liquid out through the filter cloth. After this momentary rush, however, the rate is lower.

It is difficult to estimate the critical pressure for the various materials handled in industrial filtration, or even for one material. What is a low pressure for one, may be a maximum pressure for another. Determining correct pressure for the material in hand leads to the questions, "Why are not the same pressures uniformly applicable to any material?" and, "Is there a critical pressure above which harm instead of good results?" Experience answers this last with a positive "yes," and if we might mount the scale high enough we could include in this even hard crystalline solids which are so freely filtered. The theory of an increased pressure,—based on the law for flow of liquid through orifices,—holds true only so long as the pressure employed does not change the form of the particles deposited. If we filter a wax as the solid of suspension, it is apparent that we can put sufficient pressure upon the deposited wax to cement the particles to form a homogeneous mass that would be impenetrable. When we handle gelatinous flocculent precipitates like calcium phosphate, iron hydrate, etc., we closely emulate the wax condition if we go beyond the critical pressure for these materials. Unfortunately, it is impossible to tabulate the limiting pressures critical for any material by reason of the variation of filtering characteristics of the material when precipitated under varying conditions; when suspended in different liquids; when handled under varying temperatures, densities of liquids, concentration of solids, etc. Therefore, each installation must determine for itself the critical pressure and by no other means than by empirical tests of actual operations. It is not difficult to ascertain the critical pressure in any plant if experimental runs at different pressures be made with periodic readings of the filtrate flow taken while all other factors that affect the rate of flow be maintained constant. With these readings, it is simple arithmetic to figure the rate of flow per unit area for the successive periods at which the readings were taken. A graph can then be plotted, the abscissae being the time of filtration and the ordinates the rate of flow. It is interesting to find how completely experimental observation is corroborated by such a plot.

If a low pressure is advisable in forming the first deposit in order to obtain a loose, porous cake, and if a limiting pressure is necessary in order to maintain this cake formation, we have some appreciation of the importance of the pressure employed. Save where the critical pressure is measured in feet of head rather than in pounds per square inch, the mechanics of the feeding device to the filter is extremely simple. A centrifugal pump with throw equal to the average output of the filter automatically regulates the pressure, since it cannot develop beyond a certain maximum. In filling Sweetland and other pressure leaf filters, this size pump will be too small, but the work can be done best by gravity feed through larger pipe lines. No objection should be encountered on the score that this means elevating the supply to a needless level, for this filling supply tank can be charged by the by-pass line when the safety valve throws. The use of the safety-valve on filters fed by centrifugal pumps is a new and recent procedure, although its function is purely that of preventing churning action of the impeller on the liquor when the flow falls below the throw of the pump. Naturally, the safety valve is set at a pressure less than the maximum head of the pump. This feed tank must be provided with an overflow dropping back into the main supply tank so as to prevent flooding the filling tank.

When handling materials of low critical pressure, vacuum or gravity fed filters are rightfully popular. It is a simple matter to control the vacuum pressure to 5 inches of mercury, which is, so far as the filtering force is concerned, the approximate equivalent of 5 feet gravity head. A gravity feed tank, when operating pressure-filters, can be placed at any height above the filter and consequently low pressure control on this type of filter is a simple matter. If a plant layout is made from experimental data it must not be forgotten that valves, elbows and fittings set up frictional resistance, decreasing the actual head on the filter medium and the measured height of the mean level of the liquor in the tank above the center of the filter must be in excess to the extent of this resistance, measured in feet. Gravity feed tanks will always be found a far better feeding arrangement than throttling discharge from pumps, using slow-speed centrifugal pumps, injectors, etc. In a layout it will often be necessary to elevate the liquor to be filtered into the gravity feed, and in this case a pump of approximate, but with slight excess capacity, continuously delivers into the gravity tank, with an overflow back to the source of supply.

4. Economical Limit.

In practically all phases of filtration discussion the *rate of flow is synonymous with cake building.* It is apparent that if a dry, hard cake is desired from a plate and frame filter press, the frames should be designed so that the cakes on the two sides of each frame shall join together before the rate of flow has fallen off too greatly. If the time required to build the frame solidly full is too prolonged, the cycle is bound to be uneconomical. This is best shown by a graphical analysis of rates of flow.

Representative curves are shown in Fig. 4. AB is that of a liquor containing crystalline solids, or materials of similar texture, which are free filtering products. This is practically a straight line slowly breaking into a hyperbola, and the interpretation is that the rate of flow falls off at equal increments, each increase in thickness of cake causing a corresponding increase in the resistance to the flow. The statement that "it is a straight line" is approximate and true only when applied to the usual working limits. The line eventually bends and resolves itself into a hyperbola, slowly approaching, but never reaching, zero. This curve represents that of the easiest filtered materials. The curve CD is typical of the vast majority of difficult materials handled. The initial flow is

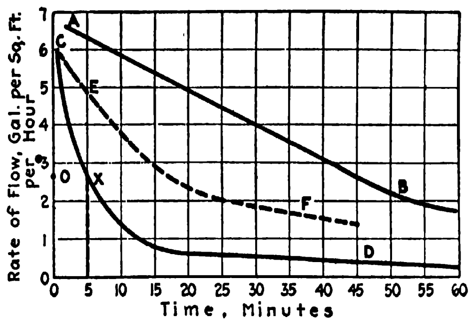


FIG. 4.—Rate of Flow Curve.

A B represents the fall in the flow of a relatively free filtering material. It approximates a straight line.

C D depicts the reduction in flow of a gelatinous or difficultly filtered material. The curve approaches a hyperbola.

E F marks the improvement in the material C D after modifying operating conditions.

high, with a rapid fall until a low rate is obtained, decrease in which is small. The goal of every filter experimenter is to change the form of this graph and make it approach AB. EF will represent the fruit of such efforts and, in lay language, means that by a modification of the material as precipitated, or by modifying the method of handling the material, it is changed to a more easily filtered liquor.

A further study of the curve CD shows us that if it were possible to work this material only for the time represented by OX we would be working at the economical part of its filtration. Such a scheme means, however, short filtering periods, and is feasible only in those types of filters wherein automatic discharge and continuous operation are had. Here we find the fundamental principle of continuous vacuum filtration, and while possibly in a sense this is not ways and means of bettering the rate of flow, it is basic in that maximum capacity is obtained, not by a modification of the filtering characteristics of the material being handled,

but by a mechanical device to meet the conditions of the material "as is." This has its importance when materials are not subject to temperature or density variation and it is required only that the deposit of the solids shall have a sensible thickness and be efficiently discharged. It is true most applications of continuous vacuum filters are on materials of a free-filtering character, but the basic idea is as explained, nevertheless.

The total flow curve is often used and from it capacity is read directly. Its curvature is not as sharp as in the rate of flow curve, and is, consequently, not quite as informative as the latter. The curve is the simple plot of time of filtering, as abscissae and total flow at time of reading as ordinate as shown in Fig. 5.

Too long a filtering period is cumulative in its evil effects. Washing is slower, cake hardness less, and the chance of a clean cleavage of the

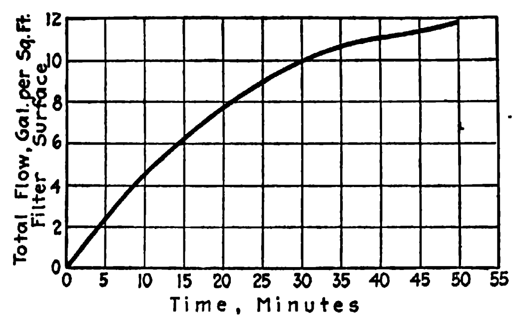


Fig. 5.—Total Flow Curve.

The quick rise of this curve indicates that the filtration is rapid at the start of the cycle and as the curve flattens out that the flow has decreased.

cake from the filter cloth jeopardized. This fault of an uneconomical cycle due to the width of the frames in plate and frame presses being too large is entirely too prevalent and is due to inadequate determination of the filtering characteristics of the material being handled. One advantage in leaf type filters is that it is not necessary to continue filtration until a hard cake is obtained. This means, then, that filtration can be discontinued at any time without jeopardizing the dryness of the cake. It is in these filters that the operator is afforded the most opportunity to effect best results as regards maximum capacity. The point to be kept in mind is that the rate of flow is constantly decreasing and when working at the low point of the curve the outflow is not commensurate with the time required. There is a mathematical means of determining the economical length of cycle which gives consideration to the washing, drying, and discharging periods, but it is well to have also in mind the general character of the rate of flow curve.

One of the most illuminating graphs arising from modern filtration developments is that known as the "economy curve." (See Fig. 6.)

Engineers will be struck with the similarity of this with that of the conventional "characteristic curve" of centrifugal pumps. The point of flexure is in both cases the economical limit. In the filtration curve, it marks the limit of the economical filtering cycle more positively than any other curve. While, in practice, the amount of liquor handled per shift may be said to be an infallible proof of the best working of the filters, the experimenter has this means of predicting that cycle productive of maximum capacity and it is more for his benefit that the curve is insisted upon in good laboratories.

The points on the curve are computations of the rate of flow per minute for each cycle, when it is assumed that the tare of the cycle

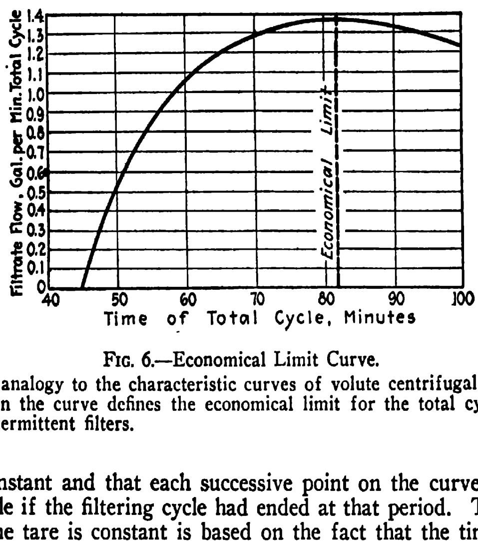


FIG. 6.—Economical Limit Curve.

Note the analogy to the characteristic curves of volute centrifugal pumps. The high point on the curve defines the economical limit for the total cycle of operations for intermittent filters.

remains constant and that each successive point on the curve is the flow for the cycle if the filtering cycle had ended at that period. The assumption that the tare is constant is based on the fact that the time of filling the filter preparatory to filtering the liquor is constant, and that the time of withdrawing the excess unfiltered liquor and admitting the wash water is almost constant, irrespective of the amount of cake deposited, that the withdrawal of the excess wash water takes practically the same time for varying filtering cycles, and that the drying, discharging operations and closing up the filter again are practically constants. The time of washing the cakes is variable with widely differing amounts of cake deposited, but, in practice, the variation in length of the washing period is small and for the purpose of this curve may be taken as a constant. Table I is the form in which it is found most convenient to record the date of a test and from it are computed the points outlining the accompanying curve.

Additional information may be gained from a study of these curves, such as a computation of capacity by planimeter methods, etc., but such data are better obtained by other methods, as will be elaborated upon.

TABLE I.

Time	Elapsed Time	Interval in Min.	Flow in Gal.	Increment in Gal.	Pres. Lb. Sq. In.	Temp. Deg. Fahr.	Dens. Deg. Bé.	Remarks
9:00	0	0	0.0	0.0	0	0	0	Filling
9:05	0	0	0.0	0.0	0	0	0	Filtering
9:08	3	3	15.0	15.0	10	182	32	Clear
9:10	5	2	25.0	10.0	12	182	32	
9:15	10	5	46.0	21.0	16	181.5	32	
9:20	15	5	63.5	17.5	20	181	32	
9:22	17	2	71.0	7.5	22	181	32	Pump stopped
10:27	17	0	71.0	0.0	0	...	..	Pump repaired
10:30	20	3	78.0	7.0	25	179	32	
10:35	25	5	90.0	12.0	25	179	32	
10:40	30	5	100.25	10.25	25	178	32	
10:45	35	5	108.75	8.5	25	178	32	
10:50	40	5	114.75	6.0	25	177	32	
10:55	45	5	119.25	4.5	25	177	32	
11:00	50	5	123.25	4.0	25	176	32	
11:05	55	5	127.0	3.75	25	176	32	Filtered
11:10	0	0	0.0	0.0	10	...	..	Washing
11:15	5	5	6.0	6.0	30	176	32	
11:18	8	3	10.5	4.5	30	177	30.5	
11:20	10	2	13.5	3.0	30	177	31	
11:22	10	2	18.0	3.5	30	178	29	
11:24	12	2	20.5	4.5	30	179	22	
11:26	14	2	28.5	6.0	30	180	8	
11:28	16	2	36.5	8.0	30	180	3	
11:30	18	2	45.0	8.5	30	181	0.5	
11:32	20	2	54.0	9.0	30	182	0	Stop
11:34	0	0	0.0	0.0	10	...	..	Drying
11:37	3	3	10.0	10.0	28	...	..	Dried
11:47	10	..	....	....	..	...	..	Discharged

COMPUTATIONS

Tare:

5 minutes filling.
5 minutes draining excess and filling with wash water.
20 minutes washing.
2 minutes draining excess water.
3 minutes drying.
10 minutes discharging.
—
45 minutes.

Points on curve:

45 minutes tare.
5 minutes filtering.
—
50 minutes cycle; 25 gallons flow divided by 50 minutes equals 0.5 gallon per minute.
45 minutes tare.
40 minutes filtering.
—
85 minutes cycle; 114.75 gallons flow divided by 85 minutes equals 1.35 gallons per minute.

The principal help from these graphs is in noting their general curvature, or shape, and comparing the curves obtained from modified operation with that of a previous run. In this respect they serve a most useful purpose, for with all factors kept constant, save a modified pressure, these graphs are indelible proof of the existence of a critical pressure and the most definite means of obtaining it.

Some may deem such a discussion too academic, and, when incorporated as the results of a test, a graph is often somewhat superfluous, but to the experimenter working out the problem it is of inestimable value. It is a big factor in maintaining a broad point of view, and it prevents premature satisfaction when better results are to be obtained by means of further research.

5. Homogeneity of Feed.

Often liquors have to be handled in which the solids of suspension are a mixture of coarse and fine particles. For maximum rate of flow agitation must be maintained in the filter so that the deposit both at the top and bottom of the filter medium is made up of a mixture of coarse, free-filtering solids and the fine, more difficult-filtering material. If classification takes place, so that the lower part of the filter cloth is coated with the coarse material and the upper part with the fine, then tapering cakes are sure to be formed and all the evils of discharging warped leaves, etc., will ensue. This leads to a point for further consideration, for if the liquor in the filter classifies and filtration is started, no amount of agitation from that time on is of any practical value. The solids that build up the cake are carried to their positions by their respective stream-lines. When a cake becomes highly resistant to filtration so that the flow is cut down, the stream lines of the liquid are weak and can carry particles only that are easily moved. This is the case when the upper part of the leaves become coated with the finer particles of suspension. No amount of uprising current which will carry the coarser particles upward can aid the deposit of the heavier particles at the top of the leaves. The stream lines are at right angles to the filter surface and strong stream lines are necessary if the velocity is to be sufficient to deposit the coarse particles on the cake surface. The above, therefore, emphasizes the fact that the initial deposit on the filter medium is vital if the best rate of flow is to be obtained.

This, then, brings out another point important in cake building: *To secure uniformity of cake, homogeneity of feed is necessary.*

6. Temperature, Viscosity and Density of Feed.

What is true of pressure as an important factor in the rate of flow is equally true of the *temperature* of the slurry and *density* of the liquid at which it is filtered. Here we have to deal not with a critical temperature or density of filtration, for with most materials practical economy dictates this before the limit which filtering efficiency requires is reached. The hotter the liquid is, the thinner it becomes, and the better will be the rate

of flow. It is, however, too often unappreciated that there is a very rapid rise in the viscosity with the increased density and decreased temperature as shown in Figs. 7 and 8. In Fig. 8, it is quite apparent that below Y

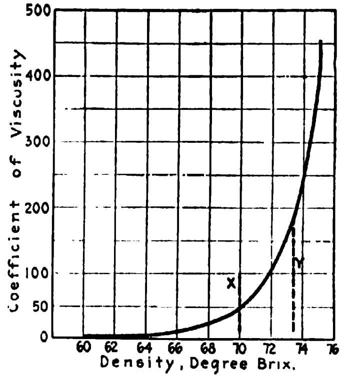


FIG. 7.—Density—Viscosity Relation.
Increasing the density increases the viscosity but far from uniformly.

a few degrees does not greatly affect the viscosity, but around X two or three degrees difference in temperature marks a distinct difference. Such information is, of course, not due to filter development, but is of value

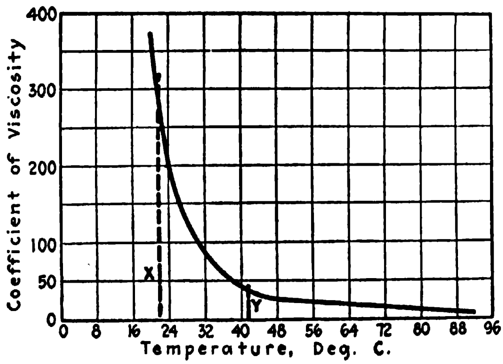


FIG. 8.—Temperature—Viscosity Relation.
Increasing the temperature lowers the viscosity but, as the curve shows, the drop is seldom uniform per degree difference of temperature.

to the operator and teaches him the need of a nice control of the temperature and density.

While *viscosity* is a big factor in the capacity of flow from a filter,

it would seem that the *surface tension* of the liquid is another factor of real practical importance. Many materials suspended in water are so slow in filtering as to defy economical operation in modern filters, yet, when heated, they become relatively free-filtering. The temperature often need not be higher than 140° F. to make a continuous vacuum filter applicable, whereas at 100° F. the capacity obtained was unsatisfactory. Pottery clays, fine whitings, crude lithopone, and other materials of like character, are today handled with excellent success in rotary drum vacuum filters, in each case, however, maintaining a temperature not lower than 160° F. An explanation of this would seem to lie in the change of the surface tension, making the separation of the solid from the liquid easier. The economy of using continuous filters is, of course, reduced by the B.T.U. consumption in heating the liquors, and so, as a straight filtering proposition, it may be difficult to show the requisite savings to warrant scrapping an existing installation. Where, however, the cake leaves the filter to be dried, feeding a heated cake to the dryer is of positive advantage and the savings in dryer operation will often more than offset the cost of heating the liquor for filtration.

For proper determination of the right temperature and density, costs of heating, evaporating, and maintaining the heat must be known so as to balance the increased work of the filters.

7. Flocculation.

Unless an auxiliary filter medium be employed, colloidal material, or solids so fine as to approach colloidal conditions, are most difficult to handle with any degree of satisfaction or economy. They are difficult to clarify without a filter-aid since they form so compact a deposit as to be almost impenetrable. Fortunately, in the majority of cases, these solids are waste products and can be coagulated, or will allow of the introduction of a filter-aid. The usual method of coagulation is by the production of a flocculent precipitate by chemical reactions. Enough attention to this point seems to be lacking, for too often the goal seems to be to add enough reagent to be able to note a sparkling liquor between the flocculent particles. It does not seem to be appreciated that an excess precipitate adds to the solids of suspension which are of themselves difficult to filter in pressure filters. It must not be inferred that the agglomeration of the particles of suspension does not aid in pressure filtration, although this theory is sometimes advanced

Centrifugal pumps are troublesome when handling flocculated material, for as soon as the outflow is less than the throw of the pump, the rotor has a churning effect which breaks up the flocculent precipitate. Every chemist knows how much harder it is to filter such precipitates in the laboratory after agitating and stirring them up so as to break up the agglomerated particles, than to handle them with the flocculent condition preserved. This difficulty is easily overcome by putting in a by-pass back to the feed tank controlled by a safety valve so that the throw of the pump is not reduced.

There is no question that *flocculation is the best means of obtaining agglomeration of the colloidal material,* but it must be remembered that *the demand is satisfied when the quantity of reagents produces no excess precipitate.* This is, of course, of less importance when only decantation methods are used.

8. Filter-Aids.

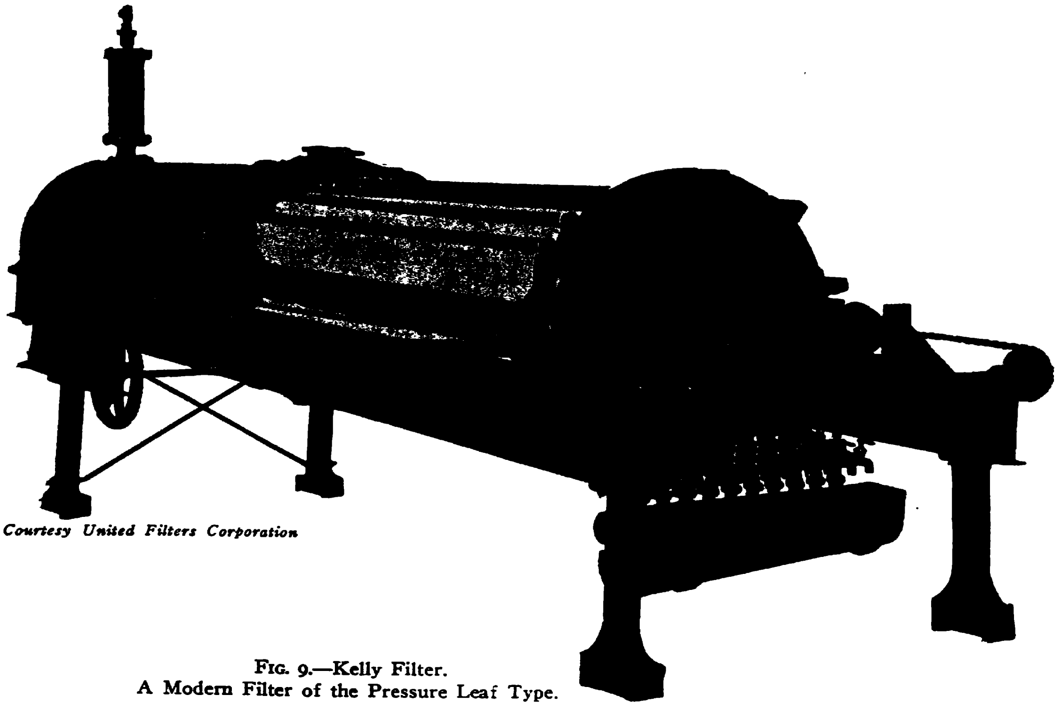
If there is added to a difficult filtering liquor before its filtration a quantity of inert, free-filtering material, it is obvious that the deposit on the filter cloth is a mixture of the free-filtering solids and the contrary precipitates. The former build up so as to preserve the porosity to a greater extent than do the latter, and consequently admit of a greater flow of filtrate. The filter-aid is added with the idea of decreasing the resistance of the solids deposited and making the liquor free-filtering, similar to that which carries crystalline or granular solids of suspension. It has been demonstrated that only a small percentage is necessary to effect marked results, but true filtering efficiency dictates the use of quantities in excess of that generally added. It is worthy of note that when good capacity flow is obtained from a filter, a corresponding increase in the volume of the cake is obtained. The greater the bulk of the cake, the better its discharge, and the filter-aid, therefore, simultaneously affects not only the rate of flow but the equally important factor,—efficient discharge.

It would seem that the combination of the flocculating idea and the filter-aid principle ought to have possibilities. It has. The idea, however, must not be to add the filter-aid as an aid to the filtration of a liquor the solids of which have been agglomerated, for to do so only partly solves the problem. In plant practice, but few instances will be found where a flocculent precipitate will not be broken up by the time the liquor enters the filters. The answer is to use the filter-aid to strengthen the structure of the flocculent precipitate by adding it to one of the defecants before its addition to the liquor. This will often require diluting the defecant, and if the water required for this is objectionable on the score of increased evaporation, no objection can be found to substituting clarified effluent for the water.

9. Maintenance of Cloth Porosity.

It is quite evident that the filter cloth must be retained in a free-filtering condition if recurring runs are to show the same capacity as the first run. It is idle to point out that thorough discharge of the cakes from the cloth is required for maintaining high rate of flow, but it is a point that experimenters are often too quick to assume when dealing with a new material. Inspection of the surface of the cloth is not an infallible means of determining that the cloth is clean. The rate of flow on succeeding runs is the only safe way.

From a view-point of clarification we have determined that open or thin cloths are the most advantageous. If we use open cloths it is natural that to arch the solids over the interstices we must let the solids



Courtesy United Filters Corporation

FIG. 9.—Kelly Filter.
A Modern Filter of the Pressure Leaf Type.

form the initial deposit with far less force than if the interstices are smaller. In consequence, open cloths require low initial pressure. The question arises, "Is there not a balance between porosity of filter fabric and rate of flow?" Most positively "Yes," but one must not confuse low and high pressures as necessarily meaning small and large rates of flow. Our ambition is to obtain the most filtrate from the filter and with the minimum expenditure of work. Consequently, low initial pressures through open cloths are often as productive of a good rate of flow as high initial pressures through dense cloths.

10. Design of Drainage Member.

The initial resistance of the filtering fabric, drainage member, etc., should be as low as possible. This fact is apparent but has been over-emphasized in some designs of filters in which excessive drainage has been provided. It must be remembered that the filtrate issues through the fabric in drops, the accumulation of which produces the filtrate flow. The drainage does not have to be very great to meet this requirement, however. In the matter of choice of filter media more attention is required. The demand is for one of low resistance to the passage of the liquid through it and if mechanical wear calls for a heavy cloth, then one of open weave is required. If too dense a cloth is used, the velocity of the initial stream lines causes the finer particles of suspension to be forced into the weave of the cloth and to embed themselves so as to cut off the porosity. With coarser weaves of filter cloth these fine particles pass through the interstices and issue from the filter as cloudy filtrate which must be refiltered. This is far better than having the filter cloth clogged so that it decreases the flow and cannot be effectively cleaned on discharging.

Chapter III.

Cake Washing.

After filtration, it is general practice to follow with the washing cycle. The function of this is, of course, to regain the valuable which would otherwise be lost in the waste solids (or, when the solids are not waste, to remove impurities from them). Of almost equal importance is the recovery of the valuable at as high a strength as possible.

The keynote of success of our modern filters is their high washing efficiency. While present-day filtration is marked more by advance in labor-saving devices than by any other feature, most economy has been effected in the better washing of the cakes, for, whereas residual soluble in the cakes was formerly counted in whole per cents, today it is in fractions of one per cent. Materials that needed exacting washes were not formerly handled in filter presses, the wash water in which almost always left some parts of the cake incompletely washed. But these materials are today handled most efficiently in the modern filters. Complete washing is possible with every modern filter, yet failure to achieve it is common. In each instance of failure a better understanding of the fundamental principle of washing would have resulted in success and made the filter far more popular.

The reason for the better results obtained is found in the method used, i.e.,—*displacement wash.* The simplicity of this method is the secret of its success. "Displacement washing" is the term used to define that wash in which the liquid entrained in the voids of the cakes is pushed ahead of the wash water without the latter mixing with the liquid. In practice, it is the simple filtering of wash water through cakes, the surfaces of which are equi-resistant.

All credit is assuredly due George Moore, who first realized the value of an equi-resistant cake and made it the foundation of his patents (both process and apparatus). His discovery was the factor which saved the cyanide process of gold extraction from being only a pretty laboratory experiment and made it the forerunner of the efficient systems now employed.

Uniform Resistance to Flow Desired.

Explanation for the practical production of an equi-resistant surface is seen by reference to Fig. 10. Take any points, A, B and C on the cakes, which may have been uniformly built up, or which may be tapering cakes with the bottom thicker than the top. The resistance to flow is the same at all of these points while filtration is taking place. The proof of

this is found in assuming that at A the resistance is less than at any other point; then, according to the law of flow of liquids (which seek the path of least resistance), a greater flow must pass through at the point A. Since, however, the muddy liquor enters the filter and clarified liquid issues from it, the greater flow at A creates a greater deposit of solids there, and this obviously increases the resistance to the flow until it is equal to the point B or the point C. It must, therefore, be acknowledged that during filtration, and at the close of the filtering cycle, the cakes present an equi-resistant surface to the flow of the filtrate.

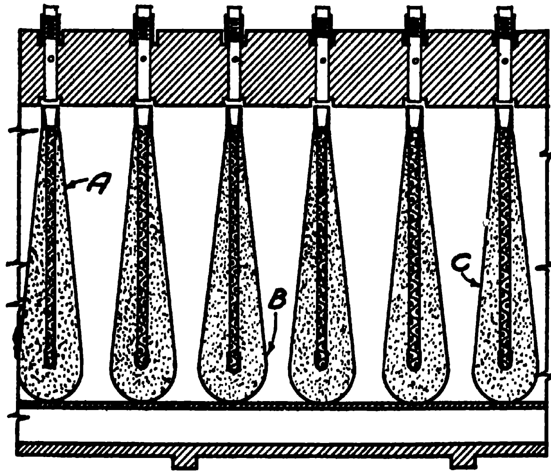


FIG. 10.—Equi-resistant Cake.

Irrespective of the thickness of the cake, whether uniform or tapering, as shown, the resistance to flow must be equal while filtration is in progress.

The advantage of an equi-resistant surface must be apparent in obtaining a uniform wash of the cake. When the wash water cannot penetrate any part of the cake faster than any other, it forces the liquid entrained in the voids of the cake through as undiluted filtrate. This, of course, is the end desired, but it must not be thought that all the soluble can be recovered without some dilution, even with the best types of filters and with the most expert manipulation. The bulk of the soluble can and should be so regained, but due to capillary attraction and dead-end pores of porous material some soluble is retained and lags behind that forced out from the interstices of the cake. This liquid is recoverable by diffusion with the wash water and is regained as a sweet water, or weak liquor.

These facts are brought out in the graph known as the "Washing Curve" shown in Fig. 11. This is a plot obtained from periodic readings

of the amount of wash filtrate flowing, and its density. The abscissae are the gallons flow and the ordinates the density.

Wash Water Displacement of Filtrate.

Assuming the density of the filtrate to have been 32° Baumé, the curve of the theoretical ideal displacement wash is seen to be a broken straight line and is interpreted as meaning that all of the soluble is recovered at the high density and when all is forced out the density falls to that of the wash water. This is, as explained above, impossible in practical

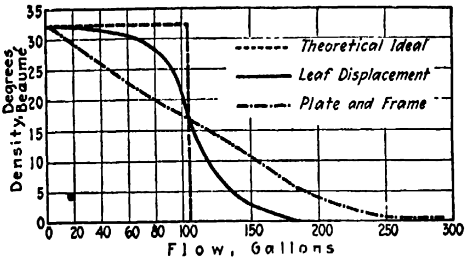


FIG. 11.—Change of Density of Wash Filtrate.

The theoretical ideal is complete displacement of all strong liquor without any dilution. The leaf displacement approaches the theoretical and represents good practical operation. The plate and frame curve indicates excessive dilution, so often found in practice when washing the cakes in this type of filter.

operation and has its value only when serving to note the efficiency of the practical operation.

The leaf-displacement curve is typical of good operation in leaf type or continuous filters. It will be noted that there is a gradual fall from the maximum density before the sharp break occurs. The explanation for this is that the viscosity of high density liquids is greater than that of the wash water or low density liquids. When washing commences, the cakes present an equi-resistant surface, but as the wash water penetrates the cake some parts of the cake are made slightly less resistant, so that the water flows through somewhat faster at such points. The turn of the curve before reaching zero is the result of the capillary attraction above referred to.

Having discussed the principle of washing in general, let us now consider specifically the washing efficiencies of different types of filters, i.e.:

(1) Plate and frame presses and leaf filters
(2) Continuous filters
(3) Open gravity filters.

1. Plate and Frame Presses and Leaf Filters.

The curve depicting the wash in plate and frame presses is representative of that obtained from alternative plate system of washing. Here, the wash water finds channels and quickly weakens the strong effluent causing a fall in the specific gravity. For the same reason, an effluent of a gravity equal to the wash water is obtained only by using excessive quantities of wash water. The reason for this is quite evident

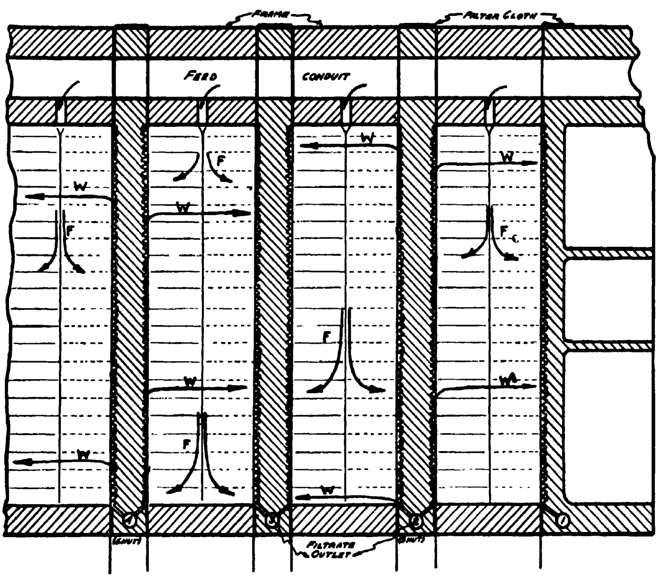


FIG. 12.—Typical Cross Section—Plate and Frame Press. (Showing Stream Lines of Filtrate and Wash Water.)

While filtering, all cocks on the plates are open, while washing, every other outlet is closed. Note that the wash water traverses through a double thickness of cake and that its initial travel is in a direction counter to the flow of the filtrate.

when we comprehend the conditions. In a plate and frame, or a chamber, filter press initial filtration is analogous to that of the leaf type filters, and varies from this latter practice only when the cakes on adjacent cloths in each frame meet. From that point on, the pump, feeding the chamber press, does work not of cake building but of cake compressing. This, of itself, is not a serious drawback, but it is practically impossible to compress all of the cake evenly or completely. It must also be remembered that the initial path of the wash water from the alternate plates is in a direction counter to that of the filtrate which produced the cake. This counter current of the wash water is vital. The resistance of the cake

to a counter current wash is seldom equi-resistant, for it is the exception when the frames are completely and evenly packed. Consequently, it is obvious that paths of less resistance are open to the flow of the wash water and universal practice has demonstrated the inadequacy of alternate plate methods of washing filter-press cakes.

Plate and frame presses of the sluicing type such as the Merrill press, and automatic discharge type, such as the Atkins-Schriver, employ the displacement system of washing and register marked successes in their washing efficiency. To work ordinary plate and frame presses on this system is to invite nice control if discharging troubles are not to be encountered.

Original Formation of Cakes Must Be Preserved.

From the foregoing, it is seen that the formation of the cakes must be preserved if true displacement wash is to be obtained in leaf filters. Most materials in plant operation vary from time to time in their filtering characteristics, so that in leaf filters it is generally found that there is too much unfiltered material remaining after filtration to allow the wash water to be turned on directly at the close of the filtering cycle. To do so would surely mean a dilution of the strong liquor lying in the filter and to increase unduly the weak liquor production. Practice, therefore, requires drawing the excess from the filter before the introduction of the water. This method allows materials to be washed at the end of their economical filtering cycle and is equally applicable whether the cakes are thick or thin. This feature of leaf filters is an important one and is in contrast to the operation in plate and frame filters, where the cake must be built up until it fills the frames and filtration ceases when the frames are filled. With raw materials varying in percentage of soluble, so that the material of suspension varies in amount and character, filtering until the frames are full often entails filtering long after the economical limit is reached.

Skill Required in Operation.

Unfortunately, this method of washing is successful in direct proportion to the ability of the operator. It is in his power to transfer the unfiltered material and fill in with wash water so that the cakes remain in a condition practically as equi-resistant as when finishing filtration, or, he can defeat the desired ends by failing to maintain the equi-resistant surface. It is positively important that he be instructed not only what valves to operate, but he should also be impressed with what he is trying to effect so that he can visualize the conditions inside the machine. If he fails to maintain a positive pressure, usually by means of compressed air, some cake will slough off the cloths and surely create a path of less resistance for the drainage of the wash water. The same is true if he drains or blows back the excess liquor at too high a velocity. Again, if he uses too high air pressure when holding the cakes on the leaves he is almost positive to dry the upper part of the cakes in advance of the lower part and will either crack the cake or cool it, so that in either case it is

conducive to the formation of unequal resistances to the flow of the wash water. Obviously, this makes for selective washing. Then, too, if he takes too long in substituting wash water for the excess unfiltered liquor, the conditions are the same as though he used too high air pressure. Experimentation will dictate the best pressure to use and the operator when once realizing what he must safeguard against has no trouble in effecting admirable results.

Direct Washing Method.

When handling materials that run uniformly, the filters can be designed so that the space between adjacent cakes at the end of the economical filtering cycle will be minimized. With Sweetland and Vallez type leaf filters, in which excess space in the filter is small, it is practical to switch on the wash water simultaneously with the closing of the liquor valve. The excess unfiltered liquor is forced through the cake ahead of the water and the dilution of the strong by the water is negligible. The same is true of Merrill and Atkins-Schriver type plate and frame presses.

The direct washing method, the name given this system of admitting the wash water without withdrawing the excess unfiltered material, is not only advantageous on the score of simplicity of operation and saving of time, but allows the greatest approximation to the true displacement wash. The reason is clear, for there is no possibility of any cake sloughing off the filter cloth, no cracks to be developed by air drying, and the equi-resistant condition of the cake is automatically preserved so long as there is a positive pressure maintained in the filter during the transfer from feeding liquor to admitting wash water.

It is interesting to note that the quantity of sweet water or weak liquor produced should approach as an ideal that amount which equals the volume of the voids in the cake. It has been explained that capillary and adsorptive action require something in excess of this in practice, but the actual amount required is often reduced when the impoverishment of the strong liquor is done by degrees.

By this means the gravity prevailing when fresh water is turned on is much reduced from the original gravity. In practice weak liquor washes are used for this purpose so that all water entering the process leaves it as a strong liquor. The same scheme is worked with marked success in continuous counter current decantation installations, save that a semi-dewatered solid instead of an equi-resistant surface is subjected to the weak liquor washes.

The conventional method of discharging plate and frame presses requires that the cake be hard and compact. Cases washed by displacement methods do not join together and their outer surface, therefore, is not compressed. To discharge such cakes from plate and frame presses is laborious and unsatisfactory unless effected by methods such as those used in the Merrill filter press or the Atkins-Schriver machine. In both machines the cake is cleaned out without opening the press and the sloppy cakes offer no difficulty in their discharge.

Cloudy Wash Water Preserves Equi-Resistant Cake Surface.

If displacement wash is simply the filtration of a wash water through an equi-resistant surfaced cake, why are there so few instances of cakes washed with volumes of wash water equal to the volume of the cake washed? The answer, applicable in every instance, is that the equi-resistant surface has not been maintained.

For years we were concerned with how to prevent this loss by shortening the time for withdrawing excess unfiltered liquor and filling wash water; using reduced pressure during transfer; using automatic floats for admitting compressed air, and venting excess air, etc. Today, we need not put so much importance upon these items, although they cannot be altogether done away with and each of them plays a part. We have simply carried Moore's discovery another step forward, and instead of washing with clear water we use muddied water, the solids in which are the washed solids of a previous run. Cloudy wash water cannot be satisfactorily made by mixing clear water with unfiltered liquor, for then the soluble content in the liquor will be added to the cake and if the soluble keeps on being added washing must be prolonged indefinitely.

The difference in using a cloudied wash water rather than a clear water is obvious since the filtration of muddy liquor automatically preserves the equi-resistant surface, or,—renews such a surface, if through mishap or faulty operation this condition were lost after the finish of filtration. With clear water, however, a point of lower resistance becomes more so as washing progresses. Oftentimes weak liquors below certain specific gravity are discarded because the cost of concentrating or recovering the soluble far outbalances the value of that soluble. A virtue of displacement wash is that the amount of this weak liquor is so small that it is not thrown to waste.

Arrangement of pumps, etc., for the application of this scheme varies with local layouts but the results obtained are well worth the cost of the installation. There are plenty of instances where materials like pottery clays, Fuller's earth, etc., are solids of relatively slow filtering characteristics, which are preferable to add to the water rather than to return washed solids of a previous run. Organic solids capable of fermentation, or carrying other soluble organic compounds capable of souring, should not be returned to the wash water tank. The volume of solids to have present is also for local decision. If the wash is progressing properly the wash filtrate should be of a density not far from that of the original until close to the end of the cycle, and the initial flow should never be any faster than that obtainable at the finish of the filtering cycle.

2. Continuous Filters. Spray Wash.

All of this discussion, relative to an equi-resistant surface, is equally pertinent to washing the cake in continuous vacuum filters. Here, the wash water is applied as an atomized spray, but, in theory at least, the water sprayed on the cake should, in its passage through the washing arc, envelop the cake and be equivalent to submergence. In practice,

this is approached but seldom attained. It requires far too delicate and frequent adjustment for the volume of water to be changed to accommodate changes in the filtrability of the cake deposited. There is no such thing as absolute uniformity in cake building, and likewise no uniform permeability of wash water through the deposit. Practice is determined on the basis of averages and the arc for washing extended to a point beyond that normally required, so as to be safe. If the spray is too heavy, the excess water accumulates, trickles down the ascending cake, and drains into the container mixing with the strong liquor. This is, of course, objectionable, but the operator should not go to the other extreme of applying too little water, for then air-drying commences and the wash water will often be short-circuited. It is for this reason that with cakes difficult to wash of the soluble it is advisable to augment the spray wash with a repuddling of the discharged cake with water or weak liquor, and to filter and wash it on a second machine. This makes for efficient washing, especially if the spray wash on the first machine is the effluent from the second machine. Then the strong liquor in the cake of the first machine is recovered at a high gravity.

The main weakness of the washing methods for continuous drum type filters is in the fine atomization necessary to spray the water on the cake. The water must be clear and free from pipe scale to prevent the nozzles clogging. Obstructions in the atomizers result in a coarse spray which has an injurious corroding effect on the cake. It was to overcome this weakness that the FEinc Non-Atomizing Wash was developed. The mechanics of this device is described later in Part II, Chapter VI, Section 3, on "FEinc Apparatus." When the cake compressor is used for washing the cake, the belt is made of a porous material, like burlap, or an absorbent material like wool felt. On the ascending side of the drum as many open saw-tooth troughs as required are distributed across the face of the drum and spill water not upon the cake itself but on the moving belt. More water is applied than is soaked up by the belt, or sucked through the cake by the vacuum, and the excess water travels down as a sheet draining into a collecting trough located under the lower idler. By this means more water is supplied than the cake will take, making a better approach to cake submergence; trouble from atomization is eliminated, and the control of the quantity fed to the filter is a simple matter of adjusting the position of the upper trough.

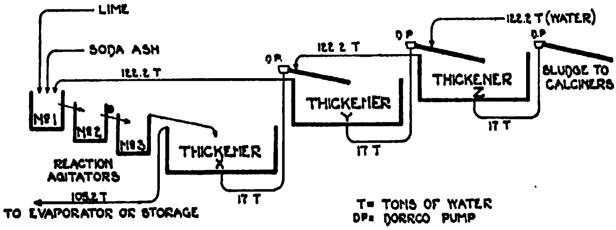
3. Open Gravity Filters.

When handling extremely free-filtering solids such as calcium sulphate from phosphoric, citric, etc., acid manufacture, it is surprising how well the soluble can be extracted in open gravity filters. These filters are usually home-made machines with false bottoms covered with cocoa matting, burlap, etc., or with the old cinder bed bottom. The one essential point is that the liquor and wash water must drain by gravity so that the cake is built up uniformly. The cake formed is granular and allows considerable flow per unit surface, but the percolation of the wash water

is slow enough so that shortly after the heavy liquid in the voids of the cake is displaced the remaining soluble has had time to diffuse through the wash water. This accounts for the admirable wash obtained in this class of filters, which obviously is confined only to those materials of an extremely free-filtering nature. New means of discharge of the cake from this type of filter is described in the chapter on "Discharging" wherein is explained how the manual labor hitherto necessary with this type of filter is now obviated.

Counter-Current Washing.

In washing cakes from liquors that are corrosive to filter cloth, or that clog the drainage member with scale deposits, the counter current system of washing used in continuous decantation systems is extremely



Courtesy The Dorr Company

FIG. 13.—Chart of Continuous Counter Current Decantation System.

The solids settled from the first thickener are repuddled with the overflow from the third thickener and settled in the second. The successive steps result in the solid going from the first to the last thickener and the wash water from the last in a counter direction. Not only is the solid well washed by this system but the wash water is enriched so as to require a minimum evaporation.

valuable. This is, in effect, step-washing wherein the overflow from one tank is of constant gravity and the underflow repuddled with a weak solution, or, in the final step,—water. The advantage of such step-washing is apparent in that all water entering the system leaves as strong liquor requiring no evaporation. The counter current of solid versus water makes the name truly descriptive. Generally displacement washing in filters should be sufficient to accomplish the results desired. It is practical with rotary continuous filters, however, to discharge an incompletely washed cake, repuddle it with fresh water, or weak liquor, and refilter and wash on a succeeding filter, or filters. In such cases, the filtrate from a weak liquor is used to repuddle cakes from strong liquors and a true counter current scheme is set up. This principle is finding an ever increasing application in leaching solubles from materials easily filtered but hard to handle in ordinary leaching methods. The substitution of filters for settling tanks makes possible some marked advantages: clarity of liquid is positive, speed of operation constant and faster, less

liquor is in process and, due to lower moisture content in cake, a better dilution of the remaining soluble in the wash water is obtained.

Washing in Plant Practice.

It is nearer fool-proof practice to have the operator work on a time or batch limit basis for the determination of the limit of the washing period. Theoretically it is more efficient to make this determination by periodic testing of the gravity of the wash filtrate, for no two batches wash absolutely evenly and, in one case, time is wasted to continue washing when the soluble has been exhausted and, in the other case, soluble is left in the cake that should be regained, unless the hydrometer shows the desired limit by test when this automatically defines when to stop. As pointed out above, however, hydrometer readings, or any other method, is no real determination if the equi-resistant surface of the cake has been lost through dropping cake, air-drying, etc. When operating on time basis the actual control of the filter operation is taken from the filter operator and put in the hands of the superintendent or his appointee. The procedure in this case is to make representative runs either with the plant machine or on a laboratory size unit in which the superintendent determines the average time necessary for the recovery of the soluble.

The control is similar when employing the batch system of washing, when the operator must take a given number of inches out of the wash reservoir or must fill the wash effluent tank so many inches. In the long run of day-in and day-out operation this practice will show a soluble loss very creditable for factory scale work in which labor is variable, sometimes dependable but other times in need of constant supervision. However, batch or time control systems are not infallible where wilful operators are employed. It happened in the writer's observation that an operator, finding the time left on his shift growing short and being behind in his schedule, opened the drain valve on the filter and ran out first the strong solution and was proceeding with the weak liquor when stopped. Such unprincipled action may not have a rightful place in this discussion save to show the necessity for recording meters or floats on strong liquor, weak liquor and even on wash water. Sewer drains should be eliminated. If recording instruments are used and conscientious operators are employed these are found to be distinct aids in keeping the data on each run. The success obtained in this one plant for preventing malicious waste, and the opportunity for better control will have an appeal to many plants having extensive batteries of intermittent filters.

The general practice of determining the end of the washing cycle by hydrometer readings needs caution. Theoretically, the gravity of the wash filtrate should be higher than that of the liquid remaining in the cake. This is approximated only as the operation approaches true displacement washing. Any lapse from this will mean that the wash has been imperfect, and the hydrometer will read considerably under that of the liquid in the cake. Irrespective of the volume of increased solution produced, it will be found that money is saved by taking a safety measure

and insisting on the operation extending beyond the point on the hydrometer which it is desired that the cake shall contain.

Daily, and in some cases, individual, tests for each run should be made for the soluble remaining in the cake. This data is valuable for factory records, and has its psychological effect on the operators. The latter is often spoiled by delays in acquainting the operators with the results of the analyses as quickly as possible. Even a conscientious workman will fail to reason out the cause for a high percentage showing in some run if it is delayed so that several runs have elapsed in the meantime. It has been often found that instead of really pumping wash water into the filter a weak liquor has been made of the wash water supply through a leaky valve, an overflow of a tank, wrong switching of valves, etc. Such troubles can usually be overcome by working up a part of the enriched material as additional weak liquor and using a fresh supply of wash water. There is no better indication of troubles than from the analytical results, and obviously, the sooner the trouble is ferreted out, the less the loss to the company. It cannot be over-emphasized how important it is for the best results that the individual operators be encouraged to become real experts on filtration. Supervisory control by the superintendent or his technologist is, at best, but periodic or intermittent, while if the operator is capable and fully instructed pride in his job automatically provides supervision of the finest quality. Nothing adds more incentive for maintaining good work than prompt reports to the operator of the analytical results. Delays in transmitting such reports are not always due to lack of desire to co-operate between laboratory and filter station, but more often the laboratory routine will not admit prompt action. Such conditions have several times been noted and without exception the chief of the laboratory appreciated the need of better co-operation and changed the laboratory routine to meet the demand.

The above sounds like the conventional hint of the importance of laboratory analyses, namely, to check plant practice, and this is of course true, but it has another importance also. When, prior to the advent of the modern filter, filter press operation was hard and sloppy work, the operators could be mustered only from strong and unskilled workers. Today filter operation is quite the reverse,—the operator is more intelligent. To such men laboratory reports are not so much checks on their work as co-operative aid. A rather remarkable evidence of this difference in the appreciation of laboratory analysis comes to mind in recalling a large chemical plant which discarded plate and frame presses and put in Sweetland filters. One operator out of five was chosen for each shift and resulted in two Italians and one old Irishman being selected. The Italians picked up the scheme of operation first but the Irishman had better uniformity in his washing results. A friendly rivalry ensued, and instead of fearing the reports from the laboratory, each would fairly hound the laboratory by telephoning for the percentage of his last run. Needless to say, these filters are praised in the most glowing terms by that management who point to the savings on the better washing of the cake, which alone turn 400 per cent per annum on the installation cost of this battery of filters.

If laboratory analyses are reports on work done, the question arises is not such a report merely a cry over spilled milk? "Yes," for that particular run, but it guides the operator on succeeding runs. If laboratory analyses show continuously good results, is it not useless work to continue making the analyses? There are instances where with uniformity of raw product, control of the operations preceding filtration are refined so that the material to be handled in the filters runs truly uniform. In such cases it is quite admissible to make the analysis per shift instead of per run, but if the raw product is liable to changes or if the batches cannot be controlled with exactness, the operator needs the analysis to verify his operation.

Chapter IV.

Cake Drying.

Drying the cakes has been ranked lowest in the cycle of filter operation, but it is now realized that this department is worthy of more attention.

To begin with, if filtration is defined as the separation of solids from liquids, then the drier the discharged cake, the closer the approximation to this definition.

Dryness of discharge is obviously advantageous in chemical manufactures when bone dry precipitates are the products turned out. Naturally, when a further drying operation is required, reducing the moisture before feeding the cake to the dryer relieves the duty of the dryer and it is generally cheaper to extract moisture mechanically than to evaporate it, using up good B.T.U.'s.

At one time drying was considered necessary only when the solids were desired as a completely dried powder. It is now realized that to dry,—meaning *to dewater*—the cake *before its discharge,* is good practice in almost all instances, including those where the solid is a waste to be discarded.

When the cake is a waste, the percentage of moisture in the cake is not a vital consideration save to guard against losses of valuable soluble in the discharged cake. If the washing operation has been efficient, drying the cake may be superfluous, but if defective washing has taken place, then decreasing the moisture content decreases the soluble in the cake. In other words, the drier the discharge, the less liquid present and consequently the less soluble thrown away.

When the solids are wastes, the drier the discharge, the easier the cakes are to handle in disposal by transportation. This is clearly demonstrated when factories located in the heart of a city have to truck these wastes to distant dumps, or lighters at wharves, when sloppy cakes spill on the pavement and increase the labor of dumping the load.

Drying the cake is fundamentally dependent on the formation of the cake. If a compact cake is produced, the voids in the cake are minimized; if a fluffy cake is formed, the percentage of voids is large. In either case the work of drying the solids is the removal of the liquids in the voids. Obviously, those cakes having low percentage of voids require less duty on the drying operation than those with high void content.

Firmness of Cake.

It is somewhat academic but nevertheless important to understand clearly the theory of cake formation which bears such a relation to drying

efficiency. When a filter is first started up or when a section of a continuous filter first dips into the liquor, the rate of flow is greatest. The flow may quite as readily be conceived as the summation of the delivery from every square inch of surface. On each unit area, cake is being deposited and its compactness is in direct proportion to the velocity of the liquid being filtered. When the velocity is high the stream lines are said to be strong, and weak when the velocity is low. Therefore, if the velocity is maintained at a high rate for a long period, the stream lines are strong and the cake firm. This, then, gives the reasoning on which better drying effect is obtained when starting with low pressure for the handling of difficult filtering materials, because this low initial pressure does not build as resistant a cake and admits of a greater flow throughout the cycle thereby. Obviously, the cake produced by strong stream lines must be a dense cake if we consider the cake as being built up by arresting the particles of suspension carried by the stream lines (its momentum being in direct proportion to the velocity of the stream line). The greater the impact upon the cake, the denser the cake produced.

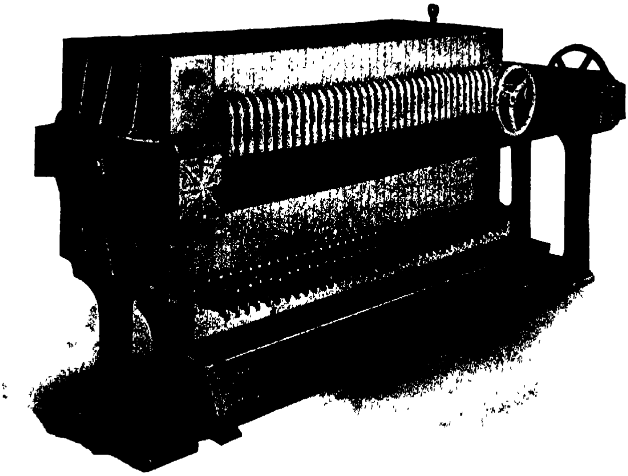
Efforts to get dry cakes have in the past been evidences of insufficient knowledge not only of the principles underlying best drying methods, but also of general economy in filtration. Until recently one of the most progressive sugar mills filtered the settlings to hard, compact and relatively dry cakes, repuddled the discharged cakes with fresh water and refiltered the mixture. The low sugar content in the final cake proved the wisdom of this method of preventing sugar losses in press cake, but careful experimentation proved that this process did not result in any profit worth the effort. The long time required to get the hard dry cake in the first presses made the impurities in the cake more soluble, so that when mixed with fresh water they dissolved and lowered the purity of the recovered sugar to a point where they made molasses rather than crystalline sugar of the recovered sucrose. Time was the factor which nullified these results. How to decrease the time required in obtaining dry cakes in frame presses is pertinent not only in the sugar industry but in chemical manufacture in general and in the pigment and color industry in particular. Usually the time consumed has its greatest bearing on the capacity of the filter since *time used for drying is time lost for filtering*.

Plate and frame filter presses stand in a class by themselves as filters delivering dry cakes. This is because the cakes are more compact than those obtained from any other type of filter. We must therefore discuss the agents at work in making hard cakes.

Cakes in Plate and Frame Presses.

In plate and frame presses the deposit in each frame of the press starts as an independent cake on the two walls of the frame which build up until they meet. Further filtration is not a pure cake building operation but is rather cake compressing. The solids are confined in the frame and as more solid enters it jams the particles closer, decreasing the voids in the cake. Filtration in filter presses, therefore, varies at this point

from filtration in leaf filters, in that the pump begins to do the work of cake compressing rather than continuing the work of cake forming. It is this compressing action that helps so materially in the production of compact filter press cakes. The principle of cake compression for dryness of discharge is unfortunately not applicable to leaf type filters. Here, the cakes must not be allowed to form so as to touch each other, or otherwise all the advantages of displacement washing in self discharge are jeopardized. Also, overcharging in pressure leaf filters is insidious in its evil effect of warping the filter leaves. Difficulty from tearing the



Courtesy T. Shriver & Company

Fig. 14.—An Up-to-Date Recessed Plate Press.
In general appearance quite similar to the plate and frame press.

cloths on distorted leaves and from straightening the drainage members is apparent, but in a well-designed and well-operated machine the filter leaves are spaced so that the cakes do not meet. When the leaves are bent out of shape it is practically an impossibility to straighten them completely, at least while in the filter, so that the original spacing is changed and some of the leaves are on closer centers. This, of course, is a condition ripe for continuing this difficulty and becomes a constant source of trouble. It is not generally understood just what produces the distortion of filter leaves. It is not that the leaves bend away from the cakes which have joined together but that, by their having joined together, the pressure between them is lowered while the exposed sides of the leaves are subject to the full pressure. This gives an excess force which, acting over the entire surface, exerts enough pressure to cause the leaves to bend in toward the joined cakes.

Cake building is assumed to have progressed according to the best

methods for clarification and capacity, yet the resistance for drying is still in the majority of cases too high. There is only one solution—make the cakes join quicker by reducing the width of the frames. Too wide a frame requires too long a cake building period and allows too great a resistance to the flow to be set up before the work of cake compression commences. It is thus seen that for any particular material there is a balance between the maximum caking capacity of a press and the dryness of the cake consistent with economic operation. These data are best determined by experimentation on the material in hand to determine its filtering characteristics without giving thought to dryness of discharge. Knowing the cake thickness obtained before the filtrate decreases to a small flow will indicate the size of the frame best suited for that material. Change in width of frame is not a new idea but has been well appreciated for many years. The manufacturers have been loath however to reduce frame widths to a point where the walls of the inlet ports are thin. This has been the limiting specification but the same area of port inlet is obtainable in several narrow inlets as in one wide port and with no greater tendency to clog the inlet than in conventional ports. This design obviates the necessity of chamber presses with the annoyance of center feeds. It is surprising what a difference ¼ in. frame thickness will make with many materials in the time required for drying. The loss of volume of cake per frame is negligible as compared with increase in cycles, ease of discharge and better all-round efficiency. Frame thickness should be determined almost entirely on the basis of drying time required.

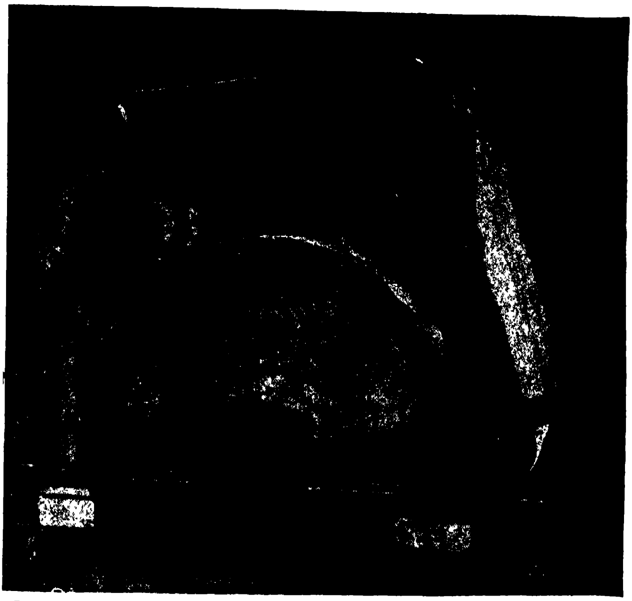
Moisture Displacement by Compressed Air.

Drying the cakes in leaf filters, therefore, must be obtained by displacing the entrained liquid in the voids of the cakes by some gas (compressed air, steam, etc.). This part of the filtering cycle is undoubtedly the weakest in the operation of leaf filters. To start with, the cakes, as built up, are high in voids, a mere examination of the cake showing the exterior of the cake to be far wetter than that against the filter cloth, and the bulk of the liquid extracted from the cakes must pass through an ever-increasing resistance until penetrating the filter cloth. This, of course, entails high duty on the drying agent.

When drying with compressed air, which is in reality filtering compressed air through the cakes, the effect is to supplant the liquid in the voids of the cake with air. This, obviously, is less support for the particles of the cake, so that there is a rearrangement of the particles,—generally spoken of as the "shrinking of the cake." The shrinking results in cracks developing which immediately form paths of less resistance for the passage of compressed air. At this stage the drying effect is negligible in comparison with the work of compressing the air and best practice is to halt the drying operation at this point.

Prevention of Cracking of Cake.

Best drying operation in leaf type and continuous vacuum filters is obtained, therefore, by proceeding in that manner which decreases the early formation of cracks. With granular and similar materials this is so practical that the difference of per cent of moisture in cakes of such materials as discharged from modern filters and moisture in cakes as discharged from filter presses is not large. When handling fine, floc-



Courtesy Filtration Engineers, Incorporated

FIG. 15.—Recent Improvement to Continuous Rotary Drum Filters. FEinc Cake Compressor for washing, dewatering and discharging the cakes.

culent materials it is more difficult to prevent early cracking. The procedure in such cases is to build up as dense a cake as possible before admitting the compressed air and to remove as much moisture in the cake at as low a pressure as possible. The means of forming the dense cake can best be determined by experimentation, but it is often found that if the initial filtration be carried on at a low pressure and allowed to rise to a point considerably less than that used during the washing operation, good results are obtained. In vacuum continuous filters, especially those of the drum type, flapping and cake-compacting mechanisms can effect this result mechanically. In any design of vacuum continuous

filters, where cake cracking cannot be avoided, there is a big saving on the duty of the vacuum pump if the automatic valve be constructed so as to shut off the suction at the time of crack formation.

Leaf type filters constructed so that the outlet of the leaves is at the top of the leaf are not as satisfactory as those that drain from the bottom. The reason for this is quite apparent, for bottom-discharge leaves drain out all the liquid, whereas the top-discharge pockets the liquid and on discharge that liquid is forced back through the cloth and mixes with the discharged cake. This is the advantage of bottom-drainage filter leaves and is the only reason for drier cakes being obtained from their use.

It is a proved fact that many materials may be discharged from leaf or continuous filters higher in percentage moisture than cakes of the same materials discharged from filter presses and yet in subsequent driers will be found to work better. This is due to the cake formation admitting a better heat conductivity and escape of the steam vapor. True, if the cake from the filter presses be broken up, then the advantage lies with the filter press cakes.

We must also remember that in true cake building the deposit against the filter cloth is the densest, while that farthest away is softest and contains a greater percentage of liquid. In dewatering this cake, the liquid must penetrate through the ever-increasing dense parts of the cake. Here, then, is the clue. If the resistance of the dense deposit is too high, the work of getting the liquid from the softer portions through it is increased. How to reduce this resistance is the question.

Cake cracking on continuous drum filters has been the prime drawback in obtaining dry cakes from these machines. Some installations are supplied with oversize dry vacuum pumps and are able to get the moisture down irrespective of cracks. This is, obviously, a poor use of power. To compress the cakes, decreasing the voids in the cakes is the best method of attack for dewatering the cakes. This is accomplished by compressing the cake on the drum of a continuous filter with a belt and rollers as described in the chapter on "FEinc Apparatus." Success with such device is obtained only when the cake is not disrupted. Rupture of the cake prevents free passage of the water in the cake through the filter cloth and gives trouble from cake adhering to the belt. If the cake is properly compressed by the belt, cracks cannot form and therefore small dry vacuum pumps can be used. This creates a saving not only in first cost of pumps but in power required for their operation. By this means cakes can often be discharged containing less than half the moisture that they would contain without this device. The dryness will vary with different materials and there is much flexibility in the choice of the cloth used for the belt and in the pressure applied to the rollers. In handling a free-filtering material the belt can be much denser and the pressure much heavier than in handling slower materials. This is accounted for since the air penetrating through a freely filtered solid is not as necessary as in the case of the difficult filtering material.

Heating.

Heating the slurry for filtering even when it is a water mixture will prove beneficial in drying the cakes. A cake from a hot liquor can be built up much thicker than from the same liquor cold, even though it be a water mixture. This enables moisture to be extracted more easily from the deposited cake and the heat carried by the solids evaporates some remaining moisture. Furthermore, if the discharged cake is fed to a dryer, the higher the cake's temperature the less heat is required in the dryer for complete evaporation of moisture. This fact led to the idea of making the cake from a continuous filter directly conveyable by wire belting to a dryer. This principle is the basis of the FEinc Drying System. In this, the cake, while still on the drum, is enmeshed in a wire belt that conveys it into a dryer. Discharge of the cake as a dry powder is effected by a beater which dislodges the dried solid from the wire belting into a covered hopper. This device completes the separation of the solid from the liquid by discharging a really dry cake from a filter.

Chapter V.

Cake Discharging.

Discharging the cakes from filters is a necessary evil representing time lost for filtering or washing. Where the cakes are valuable and subject to further processing, discharging them in a condition easiest for the subsequent treatment is a matter of technique and proper choice of machine. Discharging the cake is in many respects the keynote of efficiency in filter operation. Any type filter that cannot be operated so as to keep the cloths in a free filtering condition for recurring runs is not only inefficient, but a makeshift. Let clarification, washing or drying be faulty and discharge satisfactory, and the filters can still operate with a certain degree of economy. More filters are operating poorly by reason of incomplete, or time-consuming, discharge of the cake than for any other reason, and in too many of them this is needlessly so.

"Discharging" means *removal of the cake so as to render the filter cloth suitable for refiltration.* If discharging is complete with each cycle, the filter maintains its capacity; if incomplete, repeated operation is likely to show a decreased capacity falling off in more than arithmetical progression as the clogging effect is cumulative.

The fundamental of complete discharge is that the filter cloth (both its surface and pores) shall be cleaned 100 per cent. Surface cleaning is obviously easy and simple; *complete* cleaning is the subject for discussion.

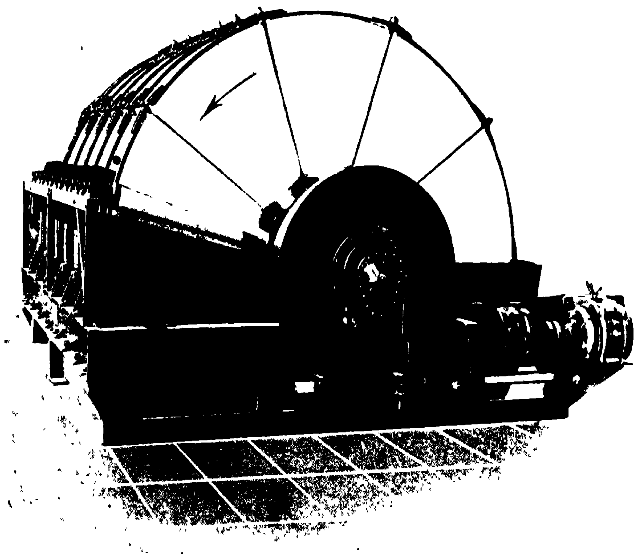
Complete cleaning signifies removal of solids from the interstices of the filter cloth. If the cakes are sufficiently firm so that in cleaving from the cloth they pull all the particles out of the cloth, complete discharge is easy. Here we find the secret of the familiar "good hard cakes" in frame presses, for a hard cake is coherent and easy to discharge. Other advantages in getting hard cakes are attendant,—the fundamental is their easy discharge.

In modern filters, especially of the leaf type, hard, compact cakes are rarely obtained that can compare with the cakes from frame presses, which are compact in form and fall out of the frames as operators move up successive frames. In modern filters, reverse current of compressed air, steam, water, etc., acts as the discharging agent, disengaging the cakes from the cloth and allowing the solids to fall by gravity or to be removed by a scraper or by sluicing streams. Reverse pressure need not be high enough to blow off the cake, although there are numerous materials that fall off while the reverse current is on. This point is vital, as evidenced by the caution every modern filter manufacturer makes of

using reduced pressures only. Obviously, their concern is in an effort to conserve the life of the filter cloth. High pressure, when using steam, represents high temperature, and, unless there is sufficient condensation to cool the temperature in the cloth, this is a factor in deteriorating the cloth.

Reverse Current Discharge.

Some of the most marked advances in filtration are due to the introduction of those continuous filters which employ reverse current discharge. Filters working on sodium carbonate, free-filtering calcium carbonate, or gypsum, may not require this means of discharge on account of their extremely granular or free-filtering characteristics, but cement slurries,



Courtesy United Filters Corporation

Fig. 16.—American Continuous Rotary Filter—Disc Type.

The filter area is arranged transverse to the axis instead of around the periphery of the drum, as in drum filters.

kaolin and other finely divided materials are inapplicable without this means of discharge. If some of this kind of material is left on the cloth, recurring filtration causes fine particles to wedge into the deposit and scale-like impenetrable mass results and most effectively blocks off further filtration.

The advantage in the use of compressed air, steam or water as the

discharging agent is dependent upon local conditions. In leaf filters reverse current through the leaves while they are submerged is often more efficacious than the same current through the leaves suspended in the atmosphere. There is good reason for this, for with the submerged leaves the water has an opportunity of getting underneath the cakes and helps release the cake when air current issues through the cloth.

Some operators are quick to condemn reverse current discharge because it will, in some cases, clear small areas on the leaves and leave the remainder undischarged. It is true that if the air can escape through a part of the cake it will not issue through the rest of the leaf forcibly enough to release the whole cake. Such conditions indicate that either too dense a cloth is being used, or else that there is some tenacious constituent in the cake which defies discharge. In this respect it is well to point out the analogy between the nap on the surface of a cotton, or cellulose, filter cloth and the hair used in plaster for walls and ceilings. Each has a binding action and the nap of the filter cloth is a big factor in causing ineffective discharge, so that metallic fabrics are often advantageous just for this point alone. A discussion of this effect of nap will be gone into later.

It cannot be too strongly emphasized that automatic discharge from leaf type filters is due to the combination of the releasing of the cake from the cloth and the fall of the material due to gravity. Therefore, any impediment that hinders either factor jeopardizes the discharge. Some cakes have a relatively high tensile strength,—are leathery in texture,—so that the mere bridging over of the cake at the top of the leaves is sufficient to hold those cakes from discharging. In such cases it is good practice to coat over, or cover, the rim of the leaves to prevent filtration at this point so that no bridging effect is possible. The same is true of any obstruction which tends to hold the cake, such as bulky side aligning lugs in Sweetland filters, unflattened drainage pipes in leaf construction, etc. If, therefore, the reverse current of compressed air is ineffective in releasing the cake from the surface of the cloth, if the cake is of too small a bulk, or is prevented from falling by some obstruction, the discharge will be unsatisfactory.

Use of Steam, Air, Water or Scraper.

Determining whether to use compressed air, steam or water, etc., as the agent for discharge, is a matter best decided in light of local conditions. Generally speaking, compressed air is best. Its pressure is easily controlled, it adds no moisture to the discharged cake, and its temperature has no deleterious effects on the filter cloth, and it distributes itself well across the entire area of the cloth. It does, of course, have a cooling effect and when handling hot liquor it may then be that steam can be substituted to better advantage. Steam is necessary when handling materials that must be maintained at high temperature, and it stands today as preferred to compressed air for this duty. The trouble with

compressed hot air is that the heat of compression added to the temperature of the hot air puts a strain on the compressor. Condensation of steam on the inner surface of the cake often facilitates discharge from leaf filters when this lubricating effect makes the cakes slide from the leaves.

Water, or any liquid, is in a sense the best reverse current because it more forcibly pushes the cake from the cloth, but its use is obviously limited. Unless the leaves are submerged, the water will often fail to remove the upper parts of the cake before it issues through the cloth at the bottom of the leaves and never issue through the upper areas. Reverse water, hot or cold, is the agent that opens the pores of the cloth more positively than any other, but it is hard to distribute across the total area of the leaves and the weight of the water in a vertical leaf puts a heavy strain on the cloth at the bottom with an excess issuing from the bottom. The most successful method of reversing water is to close the bottom discharge valves and to open an overflow at the top so that the water that passes through accumulates and balances the load at the bottom of the leaves. It is sometimes possible to feed both air and water as reverse currents and it is always possible to feed compressed air after the water has filled the filter. The bubbling action of the air stirs up the water and aids considerably in cleansing badly clogged cloths. This is especially effective if with turning on the air the bottom drain valves are opened. It is yet to be proved good practice to introduce steam with water, or after a reverse current of water, as the steam simply condenses and heats up the water, its purging effect being lost.

When cakes are thin and have not sufficient bulk to fall off of their own weight, when released by compressed air, discharge from leaf filters is impractical without submerging the leaves or without using scraping methods. If the latter must be resorted to, it must be realized that the scraper has the tendency to smear the cake into the pores of the cloth unless the reverse current of air is operating at the same time. This is the basic reason for the efficiency of discharge in continuous filters and in the automatic discharge plate and frame presses.

Discharge from Gravity Tank Filters.

The discharge from gravity tank filters has usually been by the laborious method of hand shoveling. It is simple, however, to rig up automatic means, especially if wet discharge is not objectionable. All that is required is a drainage opening and to forcibly eject the cake with a water hose. It is also possible to discharge the solids mechanically by using a rotating raking device that can be lifted free of the liquor level while filtration and washing take place and that can be lowered into the cake when ready for discharging. The weight of the rakes will be sufficient to plow into the solids. The rakes must, of course, be designed to move the mud toward the outlet provided in the tank.

Thickness of Cake.

Often thin cakes are held to be incapable of discharge by reverse current methods, whereas the trouble lies in the construction of the filter leaves. When the reverse current of compressed air is first turned into the leaves, the effect is to balloon out the filter bags, especially with dense cloths. When the bag is distended, the upper part of the bag supports the cakes from falling, even though the reverse air has efficiently disengaged the cake from the cloth. This is obviously a contrary condition for the best discharge of the cake. It is minimized by securing the cloth to the leaves at intervals across the entire area of each leaf, or by lateral stitching of the cloth to form pockets into which wooden slats, etc., drainage members, are inserted. Then the ballooning effect is decreased sufficiently so that the discharge of the cake is just as efficient at the top of the leaf as at the bottom. In continuous vacuum filters the sections are narrow enough and the wire winding is spaced close enough that ballooning of the cloth gives no trouble with these machines.

Very thin cakes are difficult to discharge but do not offer the difficulties encountered in discharging cakes that are too thick. In leaf filtration, cakes are too thick only when adjacent cakes touch each other. Such a condition is diametrically opposite to the theory of operation in this type of filter. It is fundamental that a space remain between adjacent cakes that there may be room for the free fall of the cakes when released from the filter medium. When the entire space between the leaves is filled with cake, it is rarely that the cakes can be discharged. Overcharging of a leaf filter is bad operation and indicative of poor control. If it were that the extra time required for discharge were its only disadvantage, it would not be so necessary to emphasize this point. But, overcharging is productive of warped leaves and they kill any hope of efficient filtration.

Filtrate and Cake Rating.

Overcharging is due either to too long a filtering cycle, or to too narrow a spacing of the filter leaves. Either condition is easily controlled and good filter operation demands the prompt correction of those conditions. There are liquors which, as the precipitate is commonly formed, contain too high a percentage of free-filtering material to be easily controlled in leaf type filters. Wherever possible, these materials should be handled in continuous type filters, which are more adaptable to this class of work, but where temperature, acid content, etc., call for leaf filters, the widest practical spacing should be employed, and if the solids still build too freely, then the liquid content of the material should be increased by returning some of the filtrate.

Consideration of overcharging brings out the point too often overlooked, namely, that the rating, or duty, of a filter can be either in terms of filtrate delivered or in cake built up. With very free-filtering materials the latter view is safer, and while it must be measured by the

quantity of filtrate delivered, or by the time of filtering, it is the prime consideration, for seldom is the economical limit of filtration for such materials reached by waiting for the filtrate to decrease in flow to its economical limit. To do so would build up a cake too voluminous and heavy for the best operation, both as regards washing and discharging. In design, Sweetland type filters are admirably adapted for those solids which easily fall from the leaves, for the lower half of the machine opens away from the leaves which do not have to move through the cakes. In practice, however, the cake in the lower half is often a load in excess of the power of the operating cylinder and makes for dangerous banging of the counter-weights against the shell. Also, the cake remaining in the lower half has to be removed by hoeing it out by hand, or hosing it out with water.

Nap on Filter Cloth.

Discharging the cakes from leaf type and continuous filters is practical only if the cake formed is deposited upon the surface of the medium. A surface containing nap, fibres, or similar roughness, is obviously one from which the discharge is complicated in proportion to the amount of such roughness. The cake will adhere to these surfaces in a manner quite similar to wall plaster in which the rough surface and hair form reinforcements. In discharging, therefore, it becomes essential that this factor receive attention.

Probably the simplest attack in overcoming the difficulties of nap in the filter cloth is to eliminate it from the cloth. Manufacturers of filter cloth,—up to this time, at least,—have not given any attention to the reduction of nappy surfaces, save possibly when they use selected stock such as Egyptian cotton or long staple domestic cotton, etc. This means that the local consumer must provide his own means for reduction of nap. There are several ways of effecting this, notably singeing the cloth or mercerizing it. Singeing requires considerable dexterity if it is to be successful without injuring the cloth. To merely remove the top, or apparent, nap is to do the job but partially. The nap in the interior must also be removed, and this implies that the flame when singeing must extend into the interstices. The control necessary when using dense cloths is practically too severe to be workmanlike. On thin or open cloths the singeing flame can easily extend clear through and make a real job.

Mercerizing is the process of treating the fabric with a corrosive liquor for a period, or in solution of such strength as to limit the action to the surface of the yarn or fabric. In mercerizing cotton cloths, caustic soda solution is the usual agent. The control of this process is not extremely difficult, but the causticized material must be washed clean, or else, in drying, the alkali present will concentrate and spoil the cloth. This process involves both equipment and labor that the average plant will not care to install. It is only large filter stations, using bolts of cloth at a time which will ever find it economical to go to the trouble of reducing nap. Consequently, the average installation is one in which

the nap is present and must be taken care of by other means, such as pre-coating.

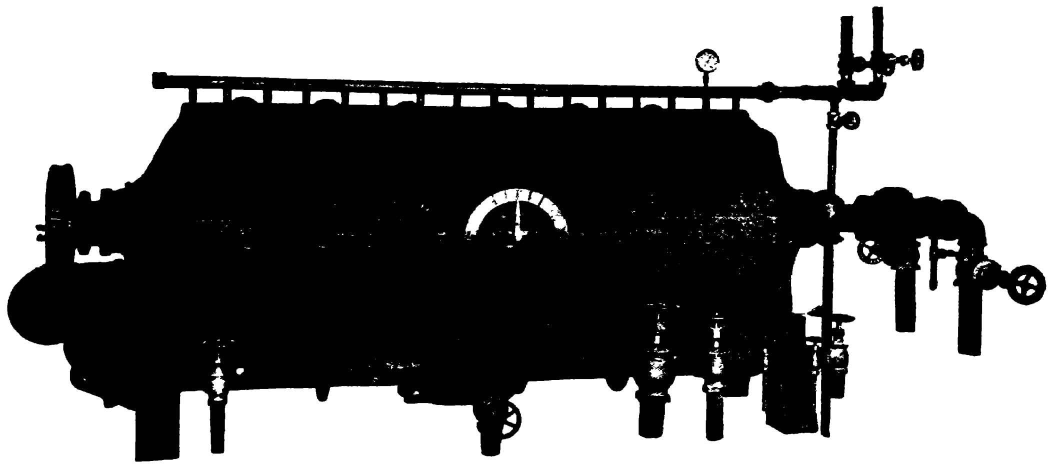
Pre-Coating Aids Discharge.

Mention has been made before of the inter-dependence of the various phases of the filter operation, but here is a very positive example. Under "clarification" we found that best practice demanded that the filter cloth be coated with a free inert material,—this process being known as "pre-coating." In discharging, this deposit serves as the means of laying down the nap necessary for easy discharge, and consequently the choice of pre-coating material is but slightly affected whether we are considering it for its discharging qualities, or for its use in aiding clarification. If in self discharge filters the material handled is free-filtering, discharge is always simple. When handling gummy, gelatinous, or colloidal materials, the discharge is quite the reverse. In fact, failure to effect a discharge of the solids from such liquors long prevented the application of modern filters to this class of material. It was in conjunction with the application of Sweetland filters to sugar refinery liquors that the proper handling of such materials became practicable. The essence of the difference between success and failure here lay in coating the surface of the cloth, thereby laying down the nap which made discharge possible. The required amount of deposit is astonishing to many who have not been familiar with the process. Time and again inspection of the filter cloth after pre-coating will show hardly any visible deposit except by scraping the surface. For instance, in pre-coating the cloths for handling the settlings in liquors in raw sugar houses in the tropics it was standard practice to make up the slurry so that one pound of filter-cel would coat 100 square feet of filter cloth. This amount, if added to clear water, contained a considerable factor of safety, as tests showed that the deposit was sufficient when one pound was distributed over 200 square feet. The test by which the operator determines whether his pre-coat has been sufficient or not is in examination of the discharged cake. This contemplates, of course, dry discharge, as sluicing discharge gives him no opportunity to inspect the cake. The surface of the cake which has been adjacent to the cloth should show a thin deposit of the filter-aid, usually as a white coating. If this coating is not complete over the entire surface of the cake it is probable that the missing portion is still adhering to the cloth, or, more likely, that it is from that area of cloth which has not been coated. Surely another proof of the effectiveness of the pre-coat is the capacity obtained from the succeeding run. There have been cases where this proof failed, however, for the material may change and the reduced flow may then be due to the characteristics of the material filtered and not to the porosity of the filter cloth. When a cloth shows signs of plugging up, these clogged areas get less and less pre-coat with each succeeding run and consequently grows less and less porous. With this in mind, therefore, it becomes economical to be generous in applying the pre-coat, so that a cloth will be safeguarded from this clogging effect from the first operation on through each succeeding operation.

Sluicing Discharge.

When filters are working on liquids containing a small percentage of solids, they are better known as clarifiers. In this class of work, the solids build up to form only a thin coating on the cloth and a discharge by reverse current methods in leaf filters, or any discharge in continuous filters, is impracticable. The customary method is to sluice the solids off the filter cloth by forcibly spraying water on the surface of the cloth. This is efficient when the solids have not penetrated the pores of the cloth. Success of such methods is evidenced by the record of the Merrill plate and frame presses in the cyanide industry and Sweetland filters in cane sugar refineries. In both these filters the sluicing is done by rocking the sluicing pipe, or manifold, back and forth so as to project the sluicing streams over the entire surface of the cloth. This operation is invariably done without opening the filter and in respect to cleanliness of operation is distinctly advantageous.

In sluicing discharge, the projected streams of water across the surface of the leaves must be of sufficient velocity and quantity to cut the cake away from the cloth and disintegrate it so that it will drain from the filter as a slurry. The angle of incidence of the stream upon the cloth must be such that the water, rebounding, will not interfere with the projected liquid. Obviously, a stream perpendicular to the leaf represents the inferior limit, while that projected parallel represents the other limit,—both of which produce zero discharge. In practice, the sluicing nozzles are located in a sluicing manifold at one corner or at one side of the filter element. The angles of incidence are then variable, being greater when the streams play against the cloth nearest the nozzles and least when playing against the cloth furthest from the nozzle. In order, therefore, to have the average effect, the best efficiency at the two extremes is sacrificed. This is the basis of the design of sluicing nozzles, although, in practice, the actual sluicing is facilitated by changing the position of the nozzles by longitudinal movement of the sluicing manifold. This makes the nozzles have changing positions from that practically adjacent to the filter cloth on one leaf to that adjacent to the cloth on the next leaf. In the latter position the angle of projection in removing the cake farthest from the nozzle is best. The entire design is based on the premise that each leaf is a flat surface at right angles to the sluicing manifold. In practice, leaves in Sweetland filters approach this condition but never realize it. Notwithstanding, however, this method of discharge is very effective when applied to cakes of small thicknesses. In Sweetland filters the sluicing manifold is located in the upper part of the filter and so long as the drainage openings of the machine in the bottom are large enough, so that there is no backing up of the sluicing water, the entire surface of the filter cloth is subjected to the sluicing streams. In Merrill sluicing frame processes the sluicing pipe is located at one,—or, in some cases, at both,—corners of the press. The usual application of this type of machine is in materials of slow but relatively uniform cake building properties. In consequence, a greater volume of cake is built



Courtesy Vallez Rotary Filters

FIG. 17.—Vallez Rotary Leaf Filter.
Pressure leaf type in which the leaves are revolvable.

up than in the usual application of Sweetland filters requiring sluicing discharge. In order to disintegrate such cakes, the streams must work on the cake nearest the outlet channel and this is at the bottom. Probably the machine most ideally designed for sluicing discharge is the Vallez filter wherein the sluicing nozzles are stationary and the leaves rotate against the projected streams. This means a more positive directing of the water against the cake and since the stream needs to reach only from the periphery to the center of the leaves, the distance that the stream must carry is only half that required in Sweetland filters.

There will be found extremely few instances where sluicing discharge is found practical and pre-coating impractical. The mere fact that the filtered solids can again be mixed with liquor, or water, defines that the solids are waste products, or subject to further processing. In either case, therefore, it is seldom that an inert filter-aid will do harm. Sluicing discharge should always be limited to those cakes of thicknesses that defy discharge in the dry state. Theoretically, sluicing discharge should be practical in combination with reverse current in that the reverse current would lift the cake from the cloth, while the sluicing streams would sweep the cake from the surface. Practically, however, the reverse current, by virtue of its ballooning effect on the cloth, jeopardizes the effectiveness of the sluicing streams. The nearest approach to a practical combination of these two methods is when steam is used as the agent for the reverse current and hot water as the sluicing agent. The water, playing upon the cloth, condenses the steam and collapses the cloth at that point so that there is no ballooning in that region. However, if pre-coating the cloth is a part of the operation, reverse currents are not necessary so long as the sluicing nozzles are working right. If one were to point to that discharge in which pre-coating is most valuable, it is probable that it would be when sluicing methods are required.

One would think that the design of the sluicing nozzles would be a matter of accurate design. Much experimentation has been made on this point but the simplest design is the one most used. Simple pipe nipples, usually ⅛ in. extra heavy pipe, threaded into extra heavy pipe as a sluicing manifold, is all there is to it.

The matter of uniform feeding of the water under pressure to all the nozzles is also a matter that would first seem to entail some niceties of design. It is required only, however, that the total area of the sluicing nozzles shall be less than the internal area of the sluicing manifold. When a long filter with leaves in narrow spacing would require an extra large pipe for the sluicing manifold, it is better mechanics to feed the sluicing water at both ends with pipes of equivalent size to a sluicing manifold. In this case, the water has to distribute through half the length of the filter only and consequently the ratio of nozzle area to manifold area is maintained with a pipe of internal area only in excess of half the nozzle area.

The longitudinal motion of the sluicing manifold, referred to above, should be uniform, especially if the filter is designed with one nozzle per side of leaf. This is not generally the practice, as some operators desire

to eliminate the operation when a sluicing nozzle throws its stream between the leaves without hitting either leaf. Operators usually pass this point with a rapid movement but in daily practice this does not pan out well. It is better to sacrifice the water and sluice automatically. The details of the mechanics covering this point (described in the chapter on "Sweetland Filters") are quite ingenious.

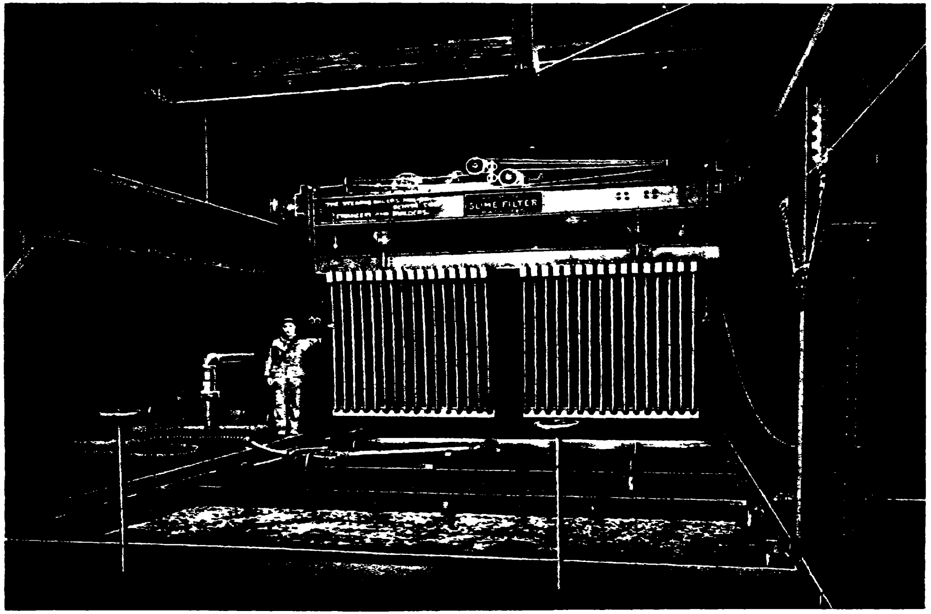
There is one other factor in sluicing discharge that has value although its amount is somewhat indeterminate. This is the rebound of the sluicing stream projected against one leaf playing upon the adjacent leaf and the possible rebound from it, duplicating the action. This seems a reasonable conjecture, although one is apt to think of a water jet being broken up into a spray if subjected to sufficient baffling. However, the stream is not that of clean water but one containing solids which undoubtedly start as accumulated solids, the effect of which must approach that of sand in sand blast operations (such as cleaning façades of buildings, iron castings, etc.). One is convinced that this is a factor after noting the discharge used on a battery of Kelly presses in a sugar mill in Cuba. Here, the superintendent in desperation resorted to the use of compressed air at 70 lbs. per sq. in., pressure from a sand blast nozzle as the means of discharge. The operator played the nozzle against the leaves near the top and the deflected blast so moved the cake that the bottom of the cloths were always clean, and ahead of the top of the leaves, without even lowering the nozzle.

Discharge from Leaf Filters.

Experience has proved that it is a fallacy to attempt to partially discharge the cakes from leaves of pressure leaf or suction filters, with the hope that the agglomerated solids will fall to the bottom of the filter, leaving the upper part of the leaves clear and in a free-filtering condition. There is always a momentary rush of filtrate at high capacity after attempting this scheme, but it does not last, for the cakes re-form and the solids present are increased so that the resistance builds up quickly. If the scheme were practical, so far as increasing the Rate of Flow is concerned, it would be hazardous when desiring to make a final discharge even if the leaves had not been warped out of shape before opening up the machine. If the leaves are on such wide centers that the dislodged cake will not bridge over between the leaves, this scheme would be better substituted by putting in more leaves on closer centers, and getting greater filter area.

Materials Difficult to Discharge.

When handling materials that cannot be effectively discharged, those filters in which the cloth can be most easily removed and replaced by clean cloths are the best the market affords. Fortunately many materials hitherto resisting all methods of effective discharge are today, by reason of our better knowledge of the art, satisfactorily handled. There can be



Courtesy Industrial Filtration Corporation

FIG. 18.—Moore Suction Leaf Filter—The Pioneer in Modern Filters. Note the immense filter area available in this design.

no refutation to the fact that inefficient operation of filters paves the way for substitute methods of clarification,—decantation, flotation, centrifuging, etc.,—and faulty discharging discredits filter operation most severely.

As is pointed out in the chapter on "Clarification," dense filter cloths are not good media for best filter operation. We have come to realize that the filter cloth is best designed when used as an auxiliary filter medium, so that we need no longer choose a cloth solely for its clarification properties. This fact alone is responsible for a considerable advance in the better discharge from many installations. No explanation is necessary for the reason for this. It is apparent that dense cloths retain particles caught in their pores much more than thin or open weave cloths.

Open cloths have a further advantage in that they allow the reverse current of the discharging agent to exert a greater force in disengaging the cake from the filter medium than do dense cloths. The latter balloon out with the introduction of the discharging agent and prevent discharge of the solids; in fact, support the cakes and allow but little of the reverse air or steam to act upon the cakes.

The effectiveness of the discharge is often inaccurately indicated by an observation of the surface of the cloth. The Rate of Flow on the next cycle is the best proof of the thoroughness of the cleaning action. Some operators working on granular material see the cake fall from the filter cloth the moment the pressure is released and see no need of further cleaning the cloths by reverse currents. To see those filters hung up while the leaves are taken out and hand scrubbed proves the utter inadequacy of the discharge. To leave only a minute film upon the cloth will in time necessitate strenuous methods in order to regain the original porosity. *Thorough discharge is necessary at all times.*

Chapter VI.

Filter Media.

Industrial filtration involves the separation of a comparatively large amount of solids from a small volume of liquid. The rate of flow of liquid through the filter medium is low; hence woven fabrics through which only a small flow is obtainable are used most successfully. Fabrics of high resistance to flow of water through them have for years constituted the typical filter cloth for industrial filtration. Today cotton duck represents one limit, the dense, and unbleached muslin the other limit, open.

Filter fabrics can be divided into two main classes; those used for neutral or non-corrosive liquors, and those for corrosive liquors. The latter are mainly special media of wool, metal, asbestos, stone, etc. For non-corrosive liquors cotton is the material used almost without exception.

Cotton Filter Cloths.

Weaves.—Cotton filter cloth fabrics are made up in duck or plain, twill, and chain weaves. Plain weave has the square or right-angle appearance of all ducking and is woven by the filling or weft passing over one warp and under the next, known as "over one under one." Twill has the diagonal lines so characteristic of its weave, and is made by weaving "over two and under two," with the next filling splitting the warp members. Chain, or as it is also known, broken twill, has a herringbone appearance and is woven with one filling going over two and under two, the next reversing this order, the third being a true twill sequence, and the next repeating the above cycle again. For each weave there is considerable modification, depending on the weights of yarn used and the number per inch. Muslins and drills are trade names for very light duck and twill weaves.

The nomenclature of the various weaves should be better standardized. At present a duck is known by a number (as 00) or by the weight per unit measure (10 oz.). Twill and chain weaves are designated by the number of warp and filling members per inch, as for instance No. 2232, where there are 22 warp members per inch and 32 fillings. There is ambiguity here, for the twills woven of different yarns under the same number of members must weigh differently. A combination of weight per unit and designation of the number of warp and filling members would do much to clarify this.

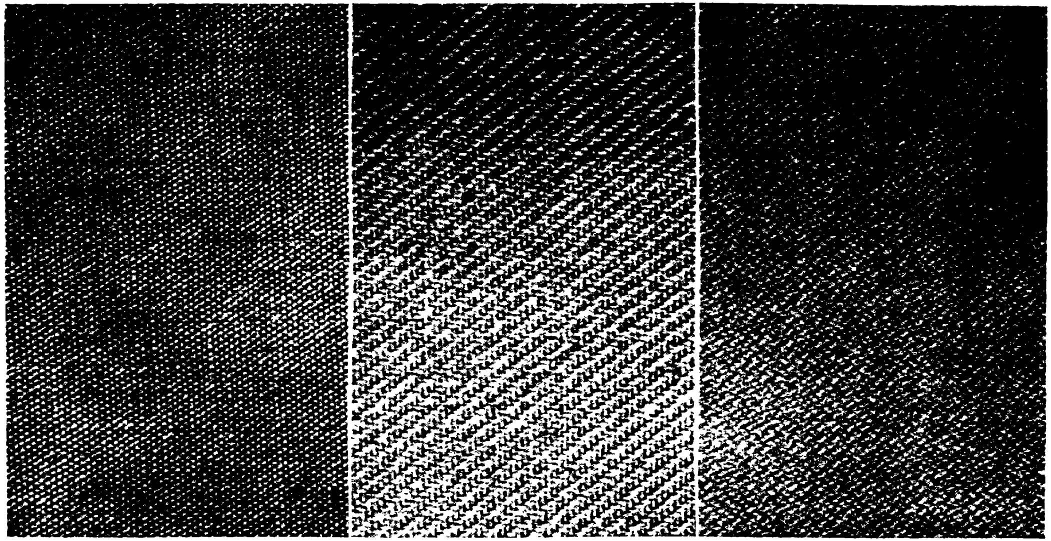
Use of Muslin.—The commercial use of unbleached muslin and other comparatively frail filter cloths marks a distinct advance in the subject of filter media, and represents the application of a principle long understood but impractical until the advent of our modern filters.

Filtration through fabrics should be surface filtration wherein all the particles filtered out of the liquor accumulate on the surface of the medium, as distinct from bed filtration wherein some of the solids are caught through the depth of the filter bed, as in sand or charcoal filters. A thin fabric has not sufficient depth to hold solids within it, whereas thick media will often hold back solids that penetrate the surface. Proof of this is furnished when the surface of a heavy twill or duck cloth will often be quite clean, while the cloth is almost impervious on account of particles lodged within the cloth.

When bag filters, gravity or suction filters, and filter presses were the only agencies at hand, strength of the fabric was the primal specification for all cloths. In bag filters, strength is required lest the weight of the liquor inside the bag burst it, and in tank filters unloading by shoveling out the cake requires a cloth of substantial strength. In filter presses the strength required is not so much due to the pressure of filtration as to the squeezing effect at the gasket joint between the abutting plates and frames. Too much emphasis has often been put upon this point. The absolute pressure on the cloth between the plates is not excessive save where the cloth is laid in a wrinkled condition and the pressure has to be increased to stop leakage at such places. To correct carelessness in laying the cloths, strong fabrics were required. For a time, manufacturers of this type of filter were too much engrossed in their schemes of drainage, washing methods, accuracy of machined surfaces, etc., and overlooked the cutting edge of the gasket surfaces. Only a strong cloth would not be cut through by these sharp edges. A rounded edge overcomes this and eliminates the breakage at this point.

Factors in Selection of Cloth.—It is obvious that the yarn used in the cloth is the determining factor in structural strength. It is also important that the cloth be dense enough to make a tight gasket joint when the press is made up. These factors have determined for the most part the specifications of the filter cloth used in filter presses.

Other factors, especially in our modern filters, affect the selection of the best filter medium. The filter cloth is fixed to the drainage member either as a sewn bag, or a wired sheet, or a clamped covering. This precludes quick changes. In consequence a cloth must have an economical life or the attendant expense of replacing the medium will make the entire filter operation excessively costly. Also, in modern filters the discharge of the cake should be without hand labor. This means automatic or semi-automatic discharging methods, the efficiency of which is largely dependent upon the filter cloth used.



Courtesy Turner, Halsey Company

Fig. 19.—Typical Filter Cloths.

Duck or Square Weave. Twill Weave. Chain Weave.

Selection of Drainage Members.

There are means of protecting a cloth so as to increase its life, but none is more effective than adequate support in the drainage member. A screen of 5 mesh per inch or greater should have a protector for light cloths. This can be a lighter or finer mesh screen, or it is cheaper and easier to envelop the drainage member in an open weave burlap. The latter cushions the filter medium against the drainage member and in addition to increasing the life of the cloth it will often ~~be found~~ to add somewhat to its capacity.

Every filter cloth is affected by the kind of drainage under it. Efforts to give the maximum drainage have resulted in excessive drainage in some cases. The foreign presses used in the breweries for sweetening off the mash are examples. The drainage member here is made up of 0.125 in. by 1 in. steel flats spaced at 0.75 in. centers and set edgewise to the cloth. Only a heavy woven fabric can safely bridge these spaces even under a low

properties. Today this is quite secondary. Most operators are realizing that the true filter medium is a layer or film of the solids which are being filtered out of the liquor. Of course, with this in mind, provision must be made for the cloudy filtrate obtained at the start of filtration. If extremely open weaves are eliminated, the amount of cloudy filtrate is not excessive for refiltration, and clear filtrate should be obtained shortly after starting up. When it is indispensable that only clear liquid be obtained, as in the case of cane sugar syrups in refineries, pre-coating the cloths with an inert, free-filtering solid automatically provides the filtering layer.

A novel and uncommon observance of a principle commonly known to all of us came to notice recently. Animal and vegetable fibers used in the manufacture of the ordinary filter fabric are absorbent. In a plate and frame installation handling a mildly caustic liquor the plant superintendent noticed that his cloth failed more quickly in the gasket portion than in the filtering area. The wash water penetrated through the filtering area but failed to wash out the soluble between the abutting gasket surfaces.

He made this part of the cloth non-absorbent by painting it with a tar base paint, thus materially increasing the life of the filter cloth with no noticeable expense.

Allowance for Shrinkage or Stretch.

The consideration of shrinkage and stretch of filter cloths is of vital importance. Every cotton yarn shrinks when wetted, and the amount varies, depending upon the physical constants of weaving, that is, the tension under which the cloth is woven, the density of the threads, and the number of intersections. Duck and chain cloths shrink much more than twill weaves. Stretch is the reverse of shrinkage and is due to mechanical pressure, usually that of reversed compressed air in discharging. Twill weaves give much more than any others and make trouble in pressure leaf filters especially. These points must be taken care of by the local user by providing extra material for liquors in which the cloth shrinks and by making up the leaves as tightly as possible where stretching is to be encountered.

Media for Corrosive Materials.

So far we have considered the material being filtered noncorrosive to the medium. Alkalies and acids are, of course, hard on vegetable and animal fiber. Some salts like aluminum sulfate have a contracting action, and unstable salts, such as some of the ammonium salts, give trouble. The degree of the deleterious effect depends upon the concentration of the liquor and the temperature. Actual test is the best means of determining whether a cotton, wool, metal, or stone medium is required.

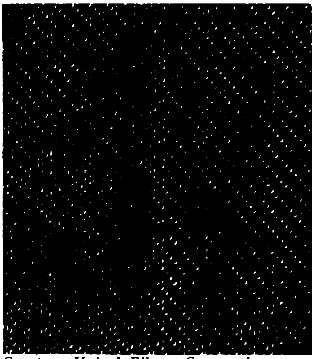
For weak caustics like milk of lime, cotton can be used economically. But wherever cottons are used with even the weakest alkalies, precautions should always be taken that the caustic does not concentrate. Letting a filter stand several days so that the cloth becomes dry before the filter is again put into operation is manifestly poor practice, as the drying of the cloth concentrates such caustic as is present. When a press is standing idle, it is good practice to fill it with water or remove the cloths and submerge them. Wool is the poorest material to use on caustics of any strength. This should be remembered where a cake filtered from an acid liquid, in which wool is a very good medium, is washed with a caustic.

Strictly speaking, the world's best acid filter medium is silica, or other inert compounds as carborundum, alundum, etc. Filtros, a porous fused silica, is typical of this class of material. Mechanically these media do not lend themselves as well to the types of industrial filters most widely used. They are sometimes faulty on account of their lack of uniform porosity and the possibility of solids penetrating the surface, never to be removed.

Metallic Cloths.

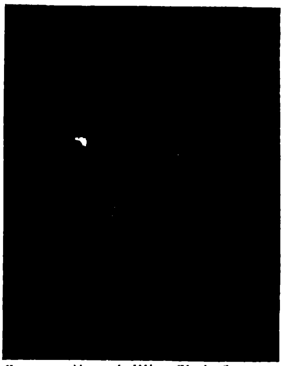
Alkali filtration prior to the advent of metallic cloths was a troublesome if not an impractical process for industrial work. Metallic cloths

today are practical media capable of withstanding the action of the strongest caustic liquors, but there are principles to be observed if their application is to be economical or efficient. Most alkaline liquors carry materials in suspension, or in solution, that have a tendency to scale formation. When handling such materials it is almost always imperative that an open weave of cloth be used, for the scaling effect is rapid upon the filter medium due to the lower pressure on the outlet of the leaf, often sufficient to induce evaporation with the consequent scale deposit. Obviously, a closely woven or rolled cloth is rendered impenetrable quicker than a more open cloth. In closed delivery pressure filters, scale formation can



Courtesy United Filters Corporation

FIG. 20.—Sweetland's Patent Metallic Filter Cloth.
The pioneer in metallic filter cloth.



Courtesy Newark Wire Cloth Company

FIG. 21.—Metallic Filter Cloth. Double Dutch Weave.

be lessened, and in some cases eliminated, by maintaining sufficient pressure on the outlet of the leaves. With hot liquors this pressure raises the boiling point at the surface of the medium and with supersaturated liquors crystallization is retarded, or eliminated, when the liquor is under pressure. The amount of back pressure required is variable with the material handled, but it will be often found sufficient when a standpipe is run to the floor above. Good design will make this a U-pipe, broken at its high point to prevent any siphon action, and returning the effluent within the observation of the operator. Such a back pressure must operate to decrease the flow, but the amount of decrease can be offset with a higher pump pressure. Too many times this decrease is exaggerated. This same argument arises where a suction is put upon the outlet of a pressure filter. In either case, the effective working pressure is the difference in pressure between that in the filter outside the leaves and that inside the leaves. Consequently, a back pressure simply subtracts from, a suction simply adds to, the effective pressure in pounds per square

inch and surely the simplest expedient to increase the working pressure is to increase the pumping pressure.

One of the factors of safety provided in the Sweetland weave is that any imperfection due to faulty workmanship can be reduced by rolling the cloth between heavy cylinders, thus closing up the imperfection. Much criticism has been leveled at this rolling, on account of the injury to the wires. If the metal is soft enough the rolling has only a small, if any, deleterious effect. If heavier wires of improperly annealed material are used it is quite evident that rolling is a poor expedient.

The improvements in twill weave instead of square weave, strength proportioned to the warp members, monel metal for iron, etc., are later-day improvements making the cloth a better medium. The wire cloth company who turned out the first commercial cloth later perfected a weave from the old Dutch cloth of commerce which has proved to offer some striking advantages. Much heavier wire can be used and the smooth finish of its surface as well as the evenness of its weave are some of its commending features.

In some liquors the metal is slowly attacked so that its life is definite. For such work there can be no discussion as to the kind of metallic cloth to use. The wire of maximum cross-section is desired and the cloth using it should consequently be selected.

Cleaning of Filter Cloths.

The filter medium often becomes fouled as a result of incrustation, either from handling supersaturated solutions or from precipitation caused by lowering the pressure of the liquor. In order that the porosity shall be maintained sufficiently to obtain production, the cloth must be cleaned with an agent that will dissolve the incrustation. This is particularly true of metallic filter cloth used on caustic liquor containing calcium compounds as precipitates. The use of an acid, such as hydrochloric, to remove these incrustations is, of course, fraught with danger to the cloth. In most instances the incrustation is unnecessary. Calcium carbonate will often deposit because the liquor contains bicarbonate. If the temperature had been raised and held at the boiling point the bicarbonate would have broken down to normal carbonate. This is very evident in beet sugar manufacture. There is a safety provision for even these liquors as they are generally handled. In closed outlet filters all that is required is that there shall be a back pressure on the medium above the actual point of precipitation. In practice this back pressure can take the form of a pipe delivering the filtrate to an outlet some feet above the filter. In a magnesia plant the scale that formed on the vertical pipe required a change of a section of the pipe each week. This, however, was a great improvement on having the filter cloth plugged up with this deposit. Of course, this remedy is not applicable to suction filters. In this case pretreatment is the only outlet, and where this is not feasible a different type of machine is probably the solution for successful handling of this material.

Chapter VII.

Theory of Filter Application.

When consideration is given to the fundamental principles of filtration in designing the machine and in operating it, no other system is as simple, direct, and positive for clarification of liquors handled in the industries. When, however, the operation or design of the filter is faulty, then centrifugals, decantation methods, flotation schemes, etc., can be substituted and found more economical.

It is rare that work done in one operation by a filter can be duplicated by other methods without repeating the operation, or supplementing with the use of a filter. The scum from flotation machines is washed and dried in filters; the residues from decantation installations is dewatered in a filter; and it is common to complete the clarification of liquids issuing from continuous centrifugals through a clarifying filter. Such methods savor too much of "two bites at a cherry" and can scarcely be considered when the correct filters are installed and operated properly. One cause for the substitution of filters is found in faulty design. This is not serious when insufficient filter area or cubical caking capacity has been provided, for such troubles are overcome by additional machines. When, however, wrong types are employed, real difficulties arise. It is becoming better recognized that no one filter can satisfy all requirements and that some types are better for some specific duties. The following classification meets general conditions, although local considerations may require radical modification in it:

Types of Filters and Their Applications.

Plate and Frame Filter Presses.—Dry discharge; material requiring frequent filter cloth removal; acids, saline liquors in machines of wooden construction.

Vacuum Leaf Filter.—Acid filtration; open tank.

Pressure Leaf Filter.—Generally applicable to all materials, but less satisfactory on acid liquors and those containing too freely filtered solids.

Vacuum Continuous Filters.—Free-filtering liquors, not too hot.

Vacuum Dewaterer Hoppers and Rotating Sand Tables.—Crystalline or granular solids too fine for good centrifugation or corrosive to centrifugals.

Surmounting Difficulties of Vacuum Filters.—Some important filter installations have been made of intermittently operated type filters where, from the nature of the material, continuous type filters would seem to have been the better machines. In these cases the continuous filters were found lacking because of inability to deliver a positively brilliant filtrate and to hold their vacuum, due to excessive cracking of the cake when air dried. Both of these difficulties are surmountable, and continuous filters should have been used. To overcome the clarity objection the valve should have been constructed with another outlet which registers with the arc in which the filter cloth first dips into the liquor and the initial cake is formed. Here is the only opportunity for cloudy liquor, and the delivery into this outlet should be returned to be refiltered. For the second there is no good reason, with drum type filters at least, for blanking off the valve at the point where the cracks allow free air to pass through. In this way the capacity of the vacuum pump is maintained, for effective suction will be found well able to hold the required vacuum.

The matter of design does not end with the selection and construction of the filter best suited for the material in hand, but must include the layout of the machine in the plant. It is most important that the layout be made so that the operator can conveniently observe the operation and handle the valves.

When plate and frame or chamber filter presses were practically the only form of industrial filter, manufacturing conditions were easier than those prevailing today. Labor was plentiful, and less costly, maintenance costs were low and time could be taken to re-handle material then that would be prohibitive today. Naturally, when an invention like the Dorr Thickener came on the market, the savings effected thereby made it decidedly evident that the old-time filter presses should be discarded.

Decantation and Flotation Methods vs. Filters.

Dorr Thickeners found advantage not only because of their automatic features, which reduce labor and obviate filter cloth renewals, but also because their counter current system of washing removes the soluble from the solids and produces strong liquor of all water used for washing. This, of course, decreases the duty of the evaporators and, therefore, lessens the cost of concentration. Besides this, Dorr Thickeners can be made alkali- or acid-resistant, and, consequently, it is possible to use them on liquors corrosive to materials used in filter construction. In fundamental principle, filters would seem to surpass Dorr Thickeners, but in actual plant practice the results often favor Dorr apparatus.

Continuous decantation systems are highly economical methods for handling large volumes of liquors, the solids in which settle readily and leave a satisfactory clear supernatant liquor. Their low labor and operating costs as well as their automatic operation are distinct advantages. They are especially applicable for the handling of calcium sulphate thrown down from phosphoric, oxalic, citric and similar acids, for they are easily constructed acid proof to these materials and effect results seldom

approached by filters working on the same liquors. By using weak liquor washes on the successive settlings so that the settlings progress from strong to weak liquors with a final mixing with fresh water, while the supernatant liquors advance from weak to strong liquors, all water entering the system leaves it as strong liquor and the settlings are discharged from the system low in soluble content. The final settlings can then be handled on a continuous type filter, if desired. The large area required for such an installation is prohibitive in some plants, but it will often pay to construct a new department for an installation.

Flotation methods of separation are effective in clarifying liquors, the solids of which are capable of being propelled upward by bombardment of the fine air bubbles ascending through the liquor. In handling greases, gums, fats, etc., this method of separation has much to commend itself, for such materials are difficult to filter and do not settle or float readily.

The advance of Dorr Thickeners, etc., into industrial application, even in the face of modern type filters, is due largely to faulty filter work rather than to inherent advantage in Dorr machines. The Dorr is simply a wonderfully clever scheme for maintaining a constant settling depth for decantation and the collection of the solids in a greatly thickened condition. The work of clarification is due to gravity, as in any decantation process, and the time element and area required are always vulnerable points where filtration should excel.

Filter Defects.

The defects of modern filters are surmountable. These difficulties are briefly summed up as difficulties with:

1. alkali or acid resistant materials of construction
2. cake discharge troubles, due to—
   a. cake building
   b. cake removal.

Remedies for these difficulties are discussed in the chapter on "Plant Practice."

Much of this trouble is not found in continuous filters. Here agitation is much simpler and changes in cake thickness make relatively much less difference in operation. The drawback to the conventional continuous filter has been its inability to discharge cakes that are thinner than ¼ in. thick. Thin cakes are hardly affected by reverse current of compressed air, and the work of discharge is almost wholly that of the scraper. Such use of the scraper is poor design, for it is too easy for the scraper to smear a thin cake into the cloth. The scraper should properly be a deflector for the cake, not a cleaver of the cake from the cloth.

Continuous Filters Made Universally Applicable.

The use of the scraper in discharging cakes from continuous filters has limited applications of these filters to those materials in which cakes

greater than 1/4 in. thick can be built up. Often the rotation of the drum has to be slowed down so that sufficient cake can be built. This lessens the effectiveness of continuous filters and narrows their field of application. If the cake is discharged by adhering to an enveloping cloth, as in the FEinc Filter, the thickness can be anything from 1/32 of an inch up. There are few materials found in industrial work that will not build a 1/32 in. cake in three minutes or less, including unthickened liquors, and, hence, it is not impossible that continuous filters may be made universally applicable.

Chapter VIII.

Auxiliary Equipment.

Faulty accessory equipment has too often caused unsatisfactory operation in filter installations. It must, therefore, be recognized as vital to good filter work and no discussion of filter operation can be thorough without attention to it. This chapter will, therefore, make some definite suggestions of outstanding importance and call the filter man's attention to the necessity of a study of his own auxiliaries in solving individual problems.

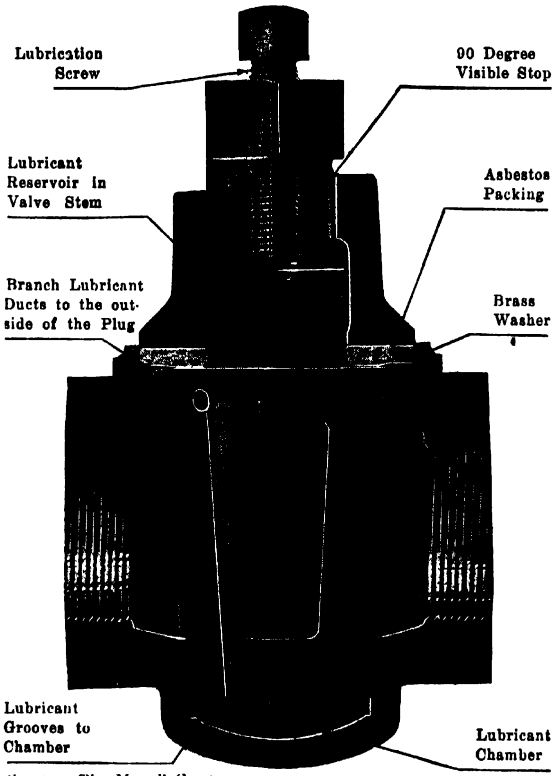
The auxiliary equipment used with industrial filters varies somewhat with the machine employed. In every case, however, piping, fittings, cocks or valves and pumps are required. For pressure filters the pump is a slurry feed pump and if compressed air is needed an air compressor is necessary. For sluicing-discharge pressure filters, a high pressure water supply is required and often has to be furnished by an auxiliary pump. In continuous filters a dry vacuum pump is always necessary, forgetting the few installations where wet vacuum pumps are applicable, and generally some exhaust pumps to carry off the filtrate from the vacuum receivers. Often an additional circulating pump is required with a continuous filter.

The piping necessary for the carrying of the slurry should be oversize. The slurry best adaptable to filtration runs high in solids. Any cessation in the flow provides a time element in which settling can take place. If the velocity of movement is not sufficient to reagitate the settled material the pipe area is reduced. Again, calcareous precipitates are common industrial materials. These have a pronounced tendency to scale on metallic surfaces. This scaling likewise reduces the pipe area. As this condition is inherent in the materials being handled it is obvious that all piping of the slurry should be as short as possible.

Corrosion of piping should be minimized by installation of resistant material. With some liquors there is present some constituent which has either a catalytic or an electrolytic action. This creates an insidious corrosion which attacks the pipe threads more violently than any other point. In such cases flange connections should be substituted for threaded fittings and the flange fittings made up in a pipe threading machine where the fitting can be tightened more securely than at the filter.

Fittings on slurry lines should never be so installed that the pipe cannot easily be inspected and cleaned. Elbows and tees should be substituted by crosses and plugs. Accessibility to a pipe line is a safety

precaution against pipes plugging up. Long sweep fittings are better than abrupt right angle turns. Erosion is less and friction loss decreased. Unions should be installed plentifully. A change in the layout is always simpler if a line can be conveniently broken without tearing down a



Courtesy The Merrill Company

FIG. 22.—Merco Valve—Lubricated Plug Cock.

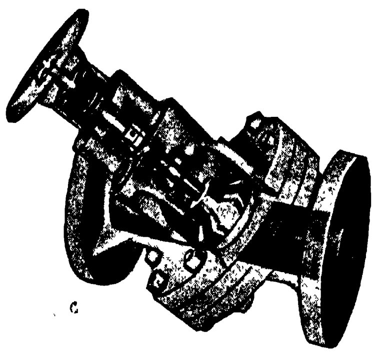
All the advantages of quick opening, direct passage, etc., of the familiar plug cock have been preserved, and by means of the lubricated plug, the valve is also non-sticking and non-leaking.

long length. Replacement of a defective or a completely blocked line is facilitated if unions are disturbed frequently.

Valves and cocks undergo heavy duty in filter work: gritty material rests on the seats, corrosion freezes the cocks and stuffing boxes on the handles are hard to keep tight. Broadly speaking, a quick opening valve is the ideal valve for filter slurries. Globe valves should be confined to gas

work only, i.e., for compressed air and steam lines. Gate valves are superior to the ordinary plug cock but the leakless, non-sticking, Merrill-Nordstrum cock is probably the best shut-off cock for filter slurries. The lubrication used in this cock is now supplied so as to be applicable to caustics, acids, hot or cold liquors. For acid liquors requiring lead valves, the Ceco disc valve is undoubtedly the best. Here is a valve with an easily replaceable seat so that a tight cock can be maintained.

Slurry circulating or feed pumps were a matter of local choice of either a ball valve reciprocating pump of plunger or horizontal type and a centrifugal pump. The pulsations and high limits of the former were considered as against the wear on impeller and leakage at stuffing box of



Courtesy The Chemical Equipment Company

FIG. 23.—Ceco Valve.

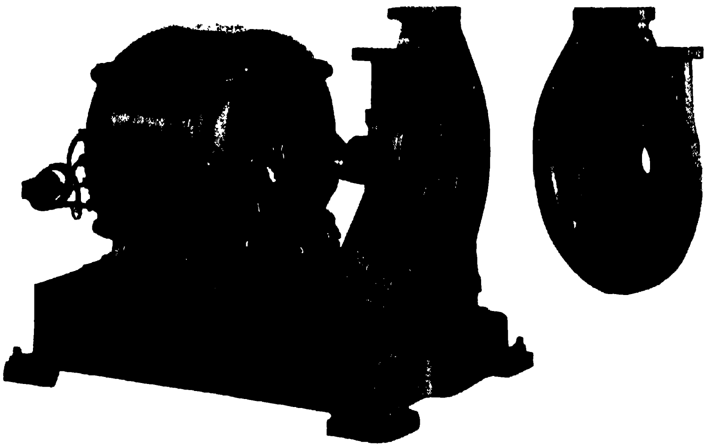
Can be constructed of lead for acid work. The line contact on closing between cone and rim of hole in disc seat insures positive cut off. The unique design permits quick and easy renewal of seating disc.

the latter. The characteristics of a centrifugal pump are in its favor, as the demand for a feed pump is large initial volume with slowly increasing pressure, and for a circulating pump for large volumes at low heads. Therefore, when the LaBour centrifugal-eductor pump came out the ideal filter press and circulating pump was found. In the LaBour type "L" pump the large clearances, the open impeller and the non-leaking stuffing box answer the drawbacks prevailing in the ordinary centrifugal pump. There is an added advantage seldom realized in this pump, namely, that more than half of the throw of the pump is educted directly from the center of the pump. This means that the churning action of the impeller in breaking up flocculent precipitates is minimized and another disadvantage of the conventional centrifugal pump is overcome.

In sluicing discharge the high pressure water is wanted in large volumes for a short period. The cleaning action is more by reason of the eroding force of the water jets than by washing off by clean water. In consequence it is good practice to run the sluicings into a settling tank and

re-use the supernatant for sluicing water supply. Nicely designed centrifugal pumps of close clearance, often of multiple stage, are the most convenient for this work. An adequate strainer is, however, necessary to catch any material likely to scour the pump.

The dry vacuum pump in continuous filters should be oversize. There is never any serious regret from having too high a vacuum pressure, while there is a serious loss if too low pressure is obtained. The vacuum pump displacement will vary with the size of the filter and the readiness with which cake cracking occurs when dewatering the solids. On clays a



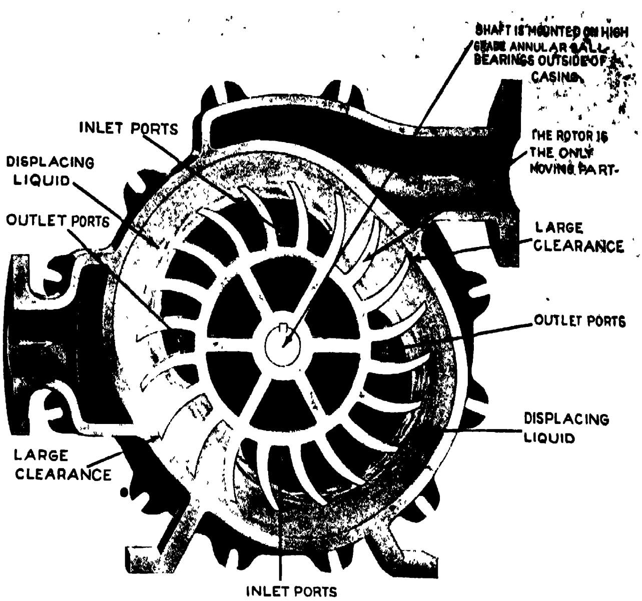
Courtesy The LaBour Company

FIG. 24.—LaBour Centrifugal-Eductor Pump.

The open impeller, large clearances (1/32 of an inch being the minimum), the eductor principle, whereby 2/3 of the throw of the pump is discharged without traversing the periphery of the pump, together with the high heads and good efficiency combine to make this an excellent slurry pump. It can be built of lead, aluminum, bronze, etc., as well as of cast iron, giving it a wide application.

fraction of one cubic foot of free air per square foot of filter surface is sufficient to maintain vacuum pressures in excess of twenty inches of mercury, while on starch, magnesia and other free cracking products 6 to 10 cubic feet per square foot are necessary to hold the same pressure. The caution against carrying over vapors that will condense in the vacuum pump, sweeping out the lubrication and even endangering the cylinder head, are pretty well observed. Condensers or coolers are advisable in order to precipitate and catch steam or other condensable volatiles before entering the pump.

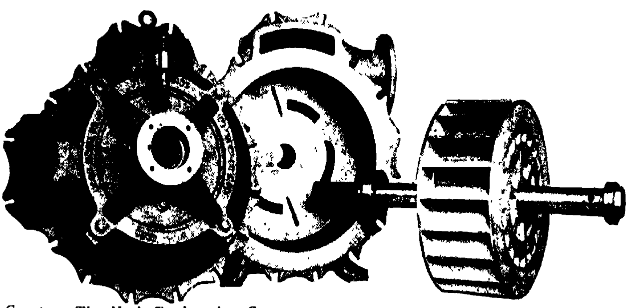
Wet vacuum pumps of the Nash Hytor design are the most practical to handle both liquid and air. The liquid must fall to a lower level than the pump, but otherwise this pump operates efficiently so long as high vacuum pressures are not necessary.



Courtesy The Nash Engineering Company

FIG. 25.—Nash Hytor—Wet or Dry Vacuum Pump.

The rarification and compression of surging liquid will handle gas or liquid with equal facility. The liquid discharged from pump cannot be raised without auxiliary pump.

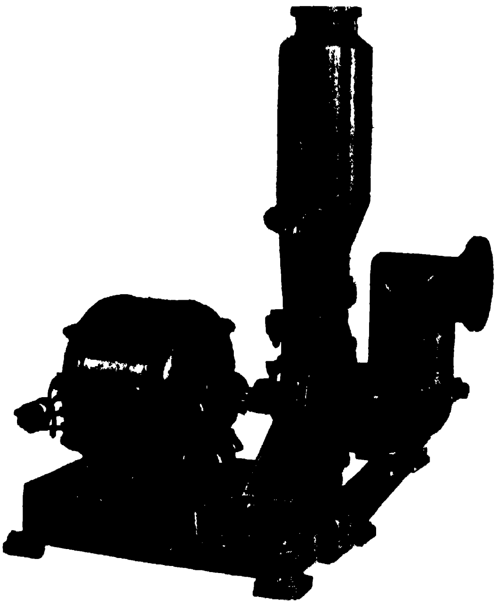


Courtesy The Nash Engineering Company

FIG. 26.—Nash Hytor—Wet or Dry Vacuum Pump.

Having only one rotating part at relatively low speeds, together with large clearances, makes this machine unique for the work accomplished.

The dry vacuum system is generally used instead of wet vacuum pumps by reason of the fact that the air volume far exceeds the liquid volume. It is more economical, therefore, to install the dry vacuum pump with its higher efficiency and to classify the filtrate and air in vacuum receivers. There remains the problem of exhausting the filtrate from these tanks.



Courtesy The LaBour Company

Fig. 27.—LaBour Self-Priming Pump.

To a standard LaBour pump a specially designed separating chamber is attached to the discharge throat. The self-priming feature allows this pump to pass air through the pump so that in addition to its use for exhausting sumps, pumping over the top of closed bottom tanks, unloading tank cars, etc., it is capable of exhausting filtrate from vacuum receivers without a check valve or an equallizing line, irrespective of the amount of vacuum.

Barometric legs or piping which extends below the tanks for a distance greater than the suction lift of the vacuum pressure obtainable offer the simplest means of draining the filtrate from the receivers. Foot valves to seal the boot of the barometric legs are not as reliable as sealing wells. The latter are simple containers, or barrels, holding a volume of liquid in excess of the cubical contents of the piping from the boot to the receiver. Whenever the elevation is insufficient to install a barometric leg, pumps must exhaust the filtrate. Centrifugal pumps are best adapted for this work but must be installed properly.

First, the receiving tank must be located above the pump so that the filtrate drains freely into the pump. Second, when using a pump that is not of itself self-priming, a check valve should be located on the discharge line at its highest point. If this check valve is located near the pump and a head of liquor rests upon it, air can trap in the pump and discharge line below the valve so that in effect a pump must compress the air to a sufficient pressure to open the check. With these pumps it is necessary to install also an equalizing line. The latter has for its function the elimination of air binding in the pump and can be located from either the suction or discharge side of the pump back to a high point on the receiver. The LaBour self-priming centrifugal pump, model "PL," is a radical advance in exhaust pumps for draining filtrates from vacuum receivers. This pump is non-air binding and being self-priming it does not require a check valve nor an equalizing line. It must, however, be located below the receiving tank and be of a capacity in excess of the filtrate flow. With this pump the receiver can be very much smaller, as it is continuously maintained free of filtrate, the pump acting as a small dry vacuum pump helping out the main pump. The performance of these pumps proves that all difficulties in exhausting filtrates are no longer necessary.

When a filter is used both to clarify a liquor and to wash the cake, the main filtrate must be kept separate from the washed filtrate. If the filtering cycle is carried on at one vacuum pressure and the washing and dewatering cycle at another, separate receiving tanks must be used for the filtrate in either case. Using a stabilizing valve to control the vacuum on the low pressure side obviates the need of using two vacuum pumps. If the two filtrates are not required to be separated, but a high and a low pressure is necessary, a stabilizing valve that will work on liquid as well as on air can be used and installed in the low pressure piping.

The auxiliaries to industrial filters are the mechanical means of controlling those factors in the plant which are so easily fixed in the laboratory.

The subject of auxiliaries can be discussed here only suggestively, but, as practical success of many installations has failed because of improper accessory equipment, the value of this chapter lies less in its suggestions than in its insistence on this fact: *auxiliary equipment is of such vital importance that it is a bad mistake to regard it as a matter of mere minor emphasis.*

PART II.

MECHANICS OF FILTRATION.

Chapter I.

Theory and Mechanics as Related to Practice.

When we speak of *industrial filtration* we have in mind its distinction from *municipal water filtration, boiler feed water filtration,* etc. It is not that the clarification required is different, nor that the work of clarifying differs, but in industrial work the percentage of solids suspended per gallon of liquid is relatively so excessive as compared with that in water filtration, that the problem of *handling solids* is the essence of all mechanical devices developed for industrial use.

The progress made in industrial filtration is best told by a strict adherence to the chronological development of filtering machines with a description of the mechanics of each. In this way the growth is seen to be rational and ever with one goal,—a more efficient machine. In filtration, progress has been most rapid within the space of two decades, and is still going on. Some of the machines discussed in the following chapters, while now in everyday operation and doing excellent work, are nevertheless fast becoming obsolescent because even while they operate well, better machines are taking their place. Though they are passing, knowledge of their development, construction and applications has value. Any one endeavoring to cover the subject of industrial filtration either as an operator or as a student will learn from them tricks of the trade that may have application in some particular problem which he may meet, or he may be guided from falling into practices that have been found inadequate in the past. Thus, their historical value may be discounted in favor of their practical value even when obsolete. Knowledge of the mechanics of all filters developed for industrial work enables one to make a nicety in choice of new machines to be installed. Understanding of the fundamentals governing the design in each machine often enables one to better the operation of existing machines.

Patentable and unpatentable features will here be discussed with no reference to the points of letters patent, information regarding which is set forth in the catalogues of the manufacturers, since this aspect is not the subject of discussion here where our interest lies rather in their academic and operative values. Likewise, no effort shall be made to describe other than the distinctive features of each machine, since detailed information is never up-to-date save through current circulars issued from the manufacturers.

In previous chapters we have focused upon the importance of the Theory of Filtration,—giving weight to the value of conditioning the

material to be filtered; the importance of controlling the factors of temperature, density, pressure, etc.,—emphasizing this more than we have the type of machine employed. And rightly so, for, given the best filter ever made but fail to control these factors and the results are miserable, while any old machine will give good results if these vital factors are well taken care of. No one is familiar with filtration who is not well advised on both the Theory of Filtration and its Mechanics. The foregoing chapters have outlined the theory. The following chapters are subdivisions of the general topic,—Mechanics. For the convenience of the reader, attention is called to the fact that each of these next chapters follows the same form so that comparisons and references may be readily made by turning to parallel paragraphs and corresponding sections in each. This chapter outline is as follows:

1. History and development of particular filter.
2. Its design.
3. Operation (cake building; washing; drying; discharging).
4. Layout.
5. Advantages.
6. Drawbacks.
7. Applications.
8. Summary of its Characteristics that led to Development of next machine.

Chapter II.

Bag Filters.

Undoubtedly the oldest and certainly the simplest of all industrial filters is the Bag Filter. Its principle of operation is familiar to any one who has been in his mother's kitchen at jelly-making time. There he has seen a cheese cloth or muslin bag serving as the filter, or strainer, into which the pulp is poured, while the clear juice is strained out through the cloth leaving the solids behind, in the bag. This is an example explaining the filtering terms: "internal filtration" or "filtration from the inside out," because the liquid penetrates from the inside of the bag to the outside while the solids remain on the inside. To clean this filter the bag is turned inside out when the solids are easily removed. This is, on a small scale, exactly the bag filter of industrial use.

While bag filters are interesting historically and as household appurtenances, it must also be remembered that there are still numbers of them in everyday commercial operation in large industrial plants. Sugar refineries still have some, and until a few years ago every refinery clarified all sugar juices through these simple filters. Sugar technologists have for many years tried to get more economic devices, but the filtering characteristics of sugar liquors resisted the application of more modern filters. In clarifying sugar liquors it is standard practice to aid filtration by agglomerating the solids of suspension by means of a flocculent precipitate. This precipitate will not hold its form under heavy pressure and consequently a bag filter with its low operating head does the work with a comfortable efficiency.

Design.—Industrial bag filters are necessarily somewhat more complex than the home-made household affairs. Added filter area per bag is obtained by folding lengthwise wide bags into open mesh enveloping bags. The open ends of the bag and envelope are attached to a special metal fitting known as a "bottle." The latter has a coarse thread at the protruding end so that the assembled bag can be screwed to a receiver fitting in the bag filter cover. This is simply a heavy cast-iron pan with a number of holes (256 in standard refinery filters), the under side carrying the receiving fittings. The filter cover rests on supports, generally cast-iron plates enclosing the bags so as to retain the heat. The filtrate, falling from the bag, drains to a low point on the floor and is delivered by separate piping to a liquor gallery. The latter is in reality an observation station where an experienced hand periodically tests the clarity from the individual filters by means of a small sampling glass on a wooden handle

He is responsible for the clarity and is in close communication with the filter operator.

Operation.—Every filter, when first started up, delivers cloudy filtrate. This may be due to the porosity of the cloth being too open, or it may be due to faulty binding of the cloth to the bottles, or to the bottles not being screwed up tight, or, perhaps, to faulty coagulation. In consequence, the filtrate man at the liquor gallery shunts all the filtrate to a re-filtration tank until the clarity becomes satisfactory. By experience it can be judged when a filter should clear up but the time will vary with

Courtesy Warner Sugar Refining Company

FIG. 28.—Sugar Refinery—Bag Filter Station.

In outer appearance the bag filters are a series of closed chambers abutting one another with large doors through which the operators are enabled to take out bags needing discharging and to replace cleaned bags. One set of filters are located at one side of the room facing a second set at the opposite side. The filters are fed from tanks overhead through feed troughs which extend along the row of filters, one for each set.

the quality of sugar handled. When a filter takes decidedly longer than expected to clear up, the filter operator is signaled to find the defect on the new filter. Here again experience on the part of the operator is necessary, for the defective bag is picked out by noting the greater flow of the unclarified liquor through one or more holes in the cover. Wooden tapered plugs are driven into these holes to shut off the particular bags that are leaking. The liquor gallery man continues inspecting filtrate at stated intervals from a filter even after it has been running clear filtrate and its delivery switched to the clear liquor reservoirs. This is necessary for under the load of the heavy sugar liquors the wrapping of the filter cloth to the bottles may slip and finally give way so that it allows muddy liquor to pass through. Also, the internal pressure on a bag will often open up a weak point and cause it to leak. Promptly, upon advice from

the liquor gallery man, the filter feed man shuts off the defective bag as explained before.

The working force in bag filtration is obviously gravity and it is a variable according to the head of liquor in the bags. Naturally, at no time can this be great without entailing an excessively strong filter medium. A thin fabric will not stand either the bursting force of the weight of the liquor or the wear and tear of repeated cleaning. A strong yarn twill weave is the popular fabric for this work. The enveloping bag is an open mesh weave of hose duck or an open netting variety, and must

Courtesy Warner Sugar Refining Company

FIG. 29.—Liquor Gallery—In Sugar Refinery.

All filtrate from all the filters is piped to one central station—the liquor gallery—where the operators periodically test the liquor for clarity and report to the filter station any change occurring in the quality of flow from any filter.

have, for its first essential, great strength. A fine mesh fish-net makes an ideal envelope.

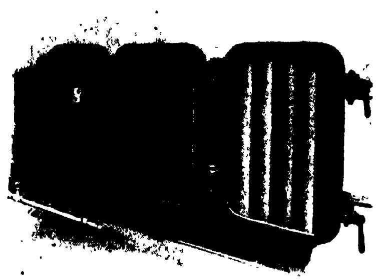
When first starting up a new filter the material to be filtered is fed upon the top of the filter cover and drained into the individual bags. Naturally, it takes some time before a filter is full, for as the head in the bags develops, filtrate is obtained, the total flow of which acts as a leakage of the incoming liquor. As the deposit accumulates in the bags, the flow decreases, and after the bags are full the operator must adjust the amount of incoming liquor so as not to overflow the filter and lose material.

Filtration continues until the flow is small. Filtration time (meaning the time of actual delivery of filtrate) varies with the material in hand, but in sugar refineries it will average 30 hours. It is understood that the flow per square foot of filter surface per hour is very small, but the tremendous area (7,500 sq. ft. in a filter of 250 bottles) enables

the plant to handle big tonnages. This size filter will handle 50,000 gallons of sugar syrup in 30 hours filtration time. This is the equivalent of 25,000 gallons in 24 hours including time out for cleaning, washing and relaying the filter. This represents the clarification of about 150,000 lbs. of sugar per day. From this an idea is obtained of the capacity of one of these machines.

After filtration there are several different methods of operation. In one, the liquor is allowed to drain until the bag is nearly empty. In another, filters drain for an hour or so; and in still another, the "sweetening off" process starts immediately.

Washing.—"Sweetening off," or washing, the sugar out of the mud in the bag is done by diluting the bag's contents with hot water and



Courtesy Warner Sugar Refining Company

FIG. 30.—Bag Filters—Door Open.

The bags are suspended from ceiling attachments—bottles—on close centers so that for a given floor space a tremendous filter area is obtained.

filtering this weakened syrup out of the bag. The hot water is applied from perforated pipes which are inserted into the bag and extend to the bottom. This is known as "sticking the bags" and is a very trying job.

Discharging.—After the bags have been sweetened off and drained practically dry, progressive refiners open up the filters and blow cool air through the bags. As soon as the filter cloth is cool enough to handle, each bag with its bottle is unscrewed from the filter cover and taken over to the washers. The bottle is untied from the bag and the enveloping bag withdrawn. The main bag is then thrown into the first of a series of tub washes. The operator at this station, by clever manipulation, turns the bag inside out, and after slight rinsing passes it through power-driven wringers into a second tub. The operator here rinses the bag and feeds it through another power wringer to another tub. Some refineries have 4 of these tubs in series,—others, less, but there is usually fresh water supplied to the last of the tubs and a constant overflow from it to each lower tub, so that in the tub of muddiest water there is a constant over-

flow into a scum-receiving tank. This mud is handled in a filter press and such sugar as present is regained.

Re-laying.—The washed cloths are then ready for re-fitting in the filters. The first step of folding the bags is done by manual labor, highly skilled in the deft handling of these unwieldy, heavy, wet bags. The open end of the folded bag is then ready for the bottle which is inserted and the cloth tied to it. The enveloping bag is next put on by means of an ingenious use of pneumatic tubes. These tubes (like the cash box tubes in department stores) first suck up the bag. Then the laborer holds the envelope around the mouth of the tube and by throwing a lever-handled valve, drops the bag into its envelope. This envelope is then tied around the bottle and the whole unit is ready to be inserted into the filter.

Advantage and Application of Bag Filters.

The dominant advantage of the bag filter lies in the low pressures used as the filtering force, thus enabling flocculent precipitates to be handled within their critical pressure limits.

Bag filters are still in use, but their operating cost is excessive in comparison with more modern types. Their use signifies inability to better time-worn methods and they stand as a challenge to American ingenuity. They are fast going out of date, and prediction is made that within a very few years they will be history only.

Bag filters are rightly industrial filters by reason of the great tonnages they handle. They are effective means of getting large filter areas in small floor spaces, but they entail much hand labor and their operation was extensive only when labor was cheap. They are not economical or efficient in light of present-day automatic devices, though they do get certain work done when other machines, so far, fail to handle it.

The obvious need for quicker and more efficient apparatus led to the development of the *filter press* which we will take up next.

Chapter III.

Plate and Frame Presses.

Plate and frame presses and recessed presses have been the standard industrial filters for more than a century. Their supremacy in American practice is now on the decline, but for "safety first" machines capable of handling any material under any condition they are not yet surpassed. Their interest is therefore more than historical for they are necessary machines with a big application throughout the chemical field.

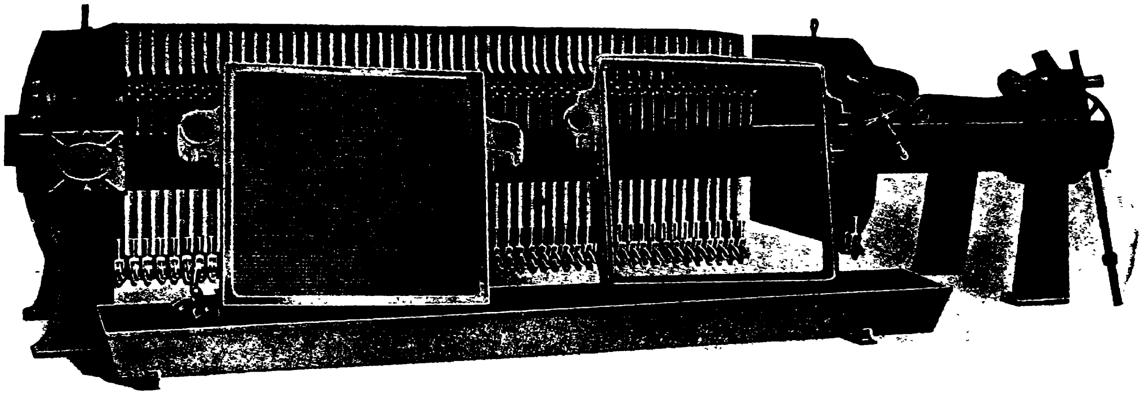
Before the advent of plate and frame presses filtration required large floor areas and the filtering force limited to low pressures. The filter press is still an economizer of floor space and capable of withstanding higher pressures than any other type. In plate and frame presses the cakes are built on parallel vertical surfaces placed at ⅜ in. to 2 in. centers so that the area for filtration is many times the area of the floor taken up by the machine. Pressures of 150 lbs. per sq. in. are often obtained in the presses extracting paraffin from petroleum distillate. Such pressures were unthought of in the filtering machines prior to the filter press and are not obtainable, with equal safety, in any of the modern filters.

If the features of large areas per unit floor space and high pressures for filtering force are the outstanding advantages of plate and frame presses today, it must be remembered that in light of previous practice these machines were labor savers, economical in filter cloth, and afforded a maximum accessibility.

Plate and frame presses enable many chemical processes to be established as commercial successes, probably none more striking than the dye industry, which would have been doubtful projects if bag or false bottom filters had been the only machines for clarifying the liquors. Every student of filtration must respect the progress in chemical manufacture due to the plate and frame press.

In comparison with modern filters there are some weaknesses but for dewatering cakes for subsequent drying plate and frame machines deliver the driest cakes. For small scale production, especially where the same machine is to be used for different materials, the plate and frames are still standard. This machine is worthy, then, of earnest endeavor to obtain and maintain highest possible filter efficiency with it.

Filter press has long been the name given to these machines, but they are rightfully pressure filters only and should not be confused with hydraulic or pneumatic presses where the force is way beyond that used in filter presses. Hereafter, plate and frame presses will be used to include recessed plate presses unless specifically designated otherwise.



Courtesy T. Shriver & Company

FIG. 31.—Plate and Frame Press.

The plates and frames in alternate succession rest on the horizontal side arms and are clamped together by the closing mechanism shown in open position on the right. In the plate with the corrugated drainage surface in the left foreground, the eye for feeding the liquor is on the left and the eye with port openings for the wash water on the right. The machined surfaces surrounding the drainage area are accurately machined surfaces forming the gasket surface by abutting similarly machined surface on the frame shown beside it.

Design.—It would be expected that with any machine so long the premier type of industrial filter that the modifications in design would be enormous. The variations range from simple, almost insignificant points to major features of closing mechanism, drainage, etc.

Fundamentally, the filter press, whether of the flush plate and frame or the recessed plate design, is a frame on which rests a series of loose plates covered with filter cloth so arranged that they may be clamped together to form a series of chambers the side walls of which are filter cloth. The caking chamber is provided by the frame in the plate and frame type and by the depression of the drainage member from the rim forming one half of the space in the recessed plate type. The conventional practice of calling these machines frame and chamber presses respectively is obviously a natural short cut.

In its elements every filter has a filter cloth, or medium, a drainage of the clarified liquid to an outlet and a space for the collection of the solid filtered out of the slurry fed under pressure to this space. Any study of design must cover these points. It is well, however, to have always in mind that in filter press operation the object is to obtain a uniform, even hard cake and with different materials these can be obtained with different designs.

The filter cloth functions both as a filter medium and as a gasket material. In practice the latter feature predominates and is the reason for heavy fabrics being required.

The drainage of the filtrate is by means of paths or channels in the corrugated or ribbed surface on the plates under the filter cloth. The outlet is a cast or bored opening to which a cock or plug is attached.

The caking space is provided by the frame, which is in reality a spacer between the plates, in the plate and frame and by the depressed surfaces on the recessed plate type.

The method of feeding the liquor to be filtered into the separate chambers is probably one of the greatest variables in the design of these filters. In recessed plate machines a hole through each plate at the center, at a corner or any other position makes each chamber communicative with the adjoining chambers. In these cases the filter cloth is sewn together or clamped together through the opening. In plate and frame the feed channel is carried in the rim so that the filter cloth acts as a gasket for the connecting joints of the feed conduit as it does for the sealing of the caking chamber.

The recessed plates or the alternate plates and frames rest, by side arms or lugs cast on each, upon the long side bars of the frame of the press. In order to seal the joints between the adjacent members a clamping arrangement or locking mechanism is provided. This mechanism pushes against the last plate, exerting a clamping pressure on each of the elements.

The frame of the machine terminates at one end in a stationary head which has its inner face corrugated to act as one side of the plate. To this head are connected the feed piping and other lines, such as wash water, steam, etc. The other end of the frame accommodates the closing device.

Inasmuch as 24 in. to 36 in. are required as the opening for cleaning the filter, or for replacing a frame or plate, the assembled plates and frames do not extend the full length of the machine. A closing bar, or piston, which transmits the pressure from the locking mechanism to the last plate, or movable head as it is generally known, closes up the distance from the assembled elements and closing device.

Elementarily, then, the filter press is a series of slabs covered with filter cloth and clamped together to form a tight container.

From an elementary construction we pass to a consideration of the present day design. This construction is based on the same fundamental principle of plate and frame operation, namely,—the formation of a good cake. Provision for washing the cake, better mechanics for drainage and delivery of filtrate, better machining of gasket surfaces, and better locking devices.

In order to obtain good hard cakes it is necessary to obtain as near as possible uniform cake building in the individual chambers. This is secured by a more generous design of inlet conduit and port areas and by a more exact determination of the width of the caking chamber for the material in hand. Plenty of opening area guards against a clogging of the feed passages so that the liquor enters the frames without obstructions cutting off the flow. By reducing the width of the frame for slow filtering slurries and by widening them for rapidly filtered materials uniform cake building with the minimum classification is obtained.

The necessity for good hard cakes of uniform density is appreciated on realizing the method of washing the cakes. In the diagram for washing filter press cakes there is depicted the formation of the cakes upon the filter surfaces of the plates. When starting filtration, independent cakes form on the surfaces. As filtration progresses the thickness of the independent cakes increases until adjacent cakes join together. When the cakes are even, so that the junction takes place simultaneously throughout the frames, conditions are correct for good washing.

Washing requires that an additional channel be provided in the design and construction of the press for the distribution of the wash water. This means that a conduit similar to the feed conduit shown in the diagram for washing cakes is provided, save that openings from it enter the even numbered plates. On operating the press, when filtration is completed, the operator closes the outlet cocks on the even numbered plates and turns on the wash water. The water then transverses the cloth on the plates and through the cakes as depicted by the arrows at "B" which represent the wash water stream line travel.

If the cakes are hard and even, the resistance to the flow of water is equal and the percolation of the wash constant throughout the press. Unequal resistance due to unevenly packed cakes, due to greater porosity of a part of a cake made up of settled coarse materials, or due to poor operation, such as failure to filter long enough to form solid cakes, etc., is sure to result in poorer washing. The latter must not be taken to mean that the soluble cannot be extracted but that it requires uneconomical amounts of wash water and time to obtain the result.

It will be noticed that the first travel of the wash water through every cake is counter current to the stream lines of the filtrate which deposited the cake. Any opportunity for movement of the particles comprising the cake surely means a new cake formation. It is physically impossible to have this movement uniform throughout the entire press, so unequal paths for the passage of the wash water result and the paths of least resistance are quickest washed.

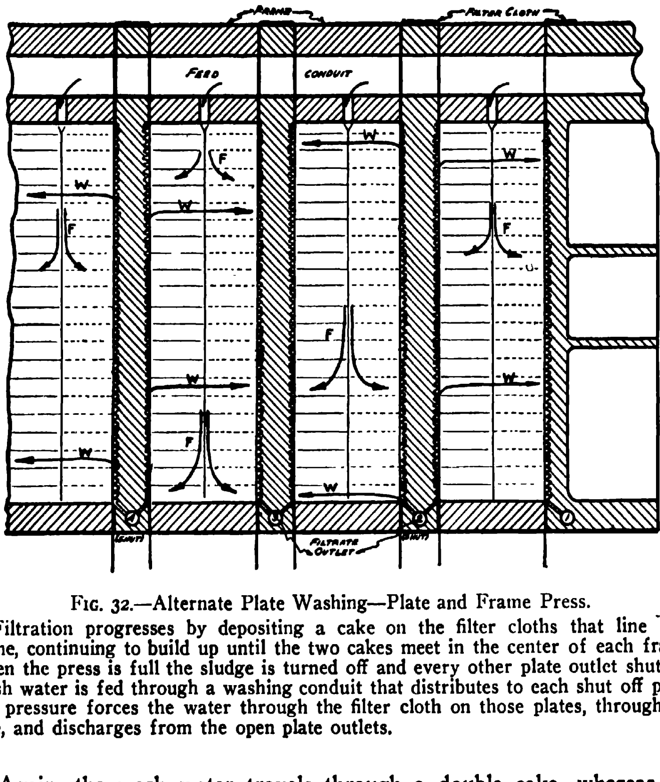


FIG. 32.—Alternate Plate Washing—Plate and Frame Press.

Filtration progresses by depositing a cake on the filter cloths that line each frame, continuing to build up until the two cakes meet in the center of each frame. When the press is full the sludge is turned off and every other plate outlet shut off. Wash water is fed through a washing conduit that distributes to each shut off plate. The pressure forces the water through the filter cloth on those plates, through the cake, and discharges from the open plate outlets.

Again, the wash water travels through a double cake, whereas the filtrate traveled through a single cake only. If there is any rearrangement of the particles of the cake there is bound to be a closer formation and a consequent reduction in volume. Any shrinkage in volume opens up a path for wash water of much lower resistance and a bad short circuit. The demand for a good hard cake of uniform resistance is, therefore, paramount in obtaining good washing of the cake.

Better determinations of the widths of frames is another step for the better production of good hard cakes. This requires simply that pre-

liminary knowledge be obtained of the filtrability of the material to be handled. If a cake one inch thick can be built up the frame can safely be made two inches thick. If a cake of only one-quarter inch can be built up the width of the frame here would best be a seven sixteenths inch. The reasoning here is quite obvious, as it is appreciated that in the latter case the resistance to the flow of liquid through the cake increases per increment of thickness much faster than in the former case.

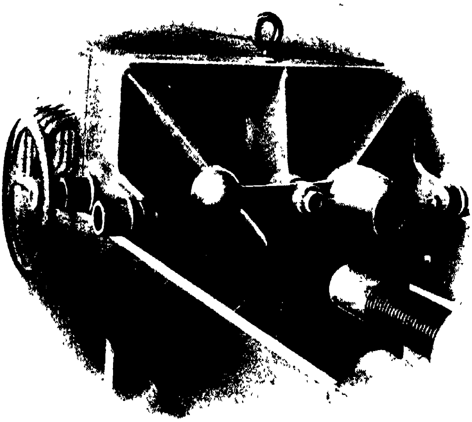
Basing the width of frame upon the filtrability of the material is modified only by a consideration of the total cycle of operation. If the shortened time for good cake building and good washing is more than offset by increased work of cleansing the greater number of frames and the renewals on filter cloth, etc., a balance between the two must determine the width of frame.

The wide application of the filter press has resulted in cases where drainage of the filtrate has proven to be an important factor in the success of the press. The filtrate flow from the average industrial liquor is the accumulation of drops of filtrate issuing through the pores of the filter fabric. In order to carry away this flow any simple, corrugated, pyramidal or other channeled surface is generally sufficient. The design contemplates that the back pressure from the internal resistance is proportional to the amount of flow. Consequently, drainage of filtrate is seldom serious for the average liquor. When using the press as a clarifier handling relatively small quantities of solids and large quantities of liquors the internal friction assumes importance. In such cases the more direct the required path for the flow of the filtrate to the outlet, the better. Coincident with handling large volumes of filtrate comes consideration of port areas for its collecting from each plate. The accepted method of caring for this is multiple ports rather than one large opening. The drainage should be first designed for collection of filtrate and secondly for the physical strain on filter cloth. The points of support for the cloth must be rounded and on sufficiently close centers to insure against the cloth failing in bridging across to adjacent supports. The most successful drainage is obtained when the pyramidal or channeled surface is covered with a close mesh wire screen. The latter provides maximum support for the cloth and free passage for the filtrate into the channels. Protecting the edges of recessed plates to prevent a cutting action on the cloth is a similar improvement provided in a press of modern construction.

A filter press is designed to be a tight container when in closed position. It is as tight as the loosest joint. Consequently, a press will be made up with excessive pressures at some joints unless every gasket surface is accurately machined and the cloth laid without wrinkles or adhering cake. Machining far more accurate than that obtainable in a lathe, planer or shaper is obtained in the best produced presses now being manufactured. Accurately ground surfaces tested to within .003 of an inch is standard today. Such practice is reflected in the quicker closing of the filter, less strain on filter cloth, thus increasing its life, and the elimination of unequal strains through the locked press.

Improved locking devices are varied enough to be the subject of an

exhaustive study, inasmuch as closing the press is time-taking and arduous. Automatic or semi-automatic means have been the goal of a great many designers. Eastick's translation of Buhler's *"Filters and Filter Presses"* goes into this subject thoroughly. Let it suffice here to point out that a closed press should be locked. If the pressure on closing the plates is obtained by toggle design, or by big step reductions, the locking is automatic. If the pressure is by direct pneumatic or hydraulic



Courtesy T. Shriver & Company

FIG. 33.—Typical Head Locking Mechanism in Plate and Frame Press.

The movable head carries its own thrust block shown in horizontal position. When rotated to the right so that the projection centers with the threaded shaft the thrust block really becomes an extension of the movable head and reduces the necessary turning of the threaded shaft. Obviously as the shaft is threaded toward the press the locking force is exerted centrally and equally against the plates and frames. Numerous devices have been designed to effect the maximum leverage on the turning of the shaft, but the key to the design is the thrust block shown here.

pressure, additional locking is required. When locked, no damage can occur if the hydraulic pump shuts down without warning.

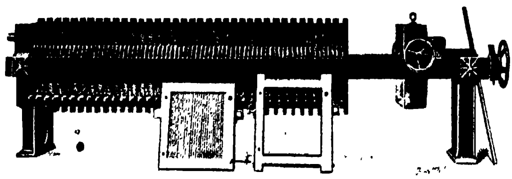
The standard filter press is open delivery type. This means that each plate delivers its filtrate into an open collecting trough or pan. Most machines have individual shut-off cocks of a quick closing design. Every open delivery washing press must have the shut-off cocks in order to carry out the washing operation. The cocks are indispensable when positive clarity is required or else one leaky cloth will nullify the work of the entire press. Plug cocks are simple and positive shut-offs and the small saving in first cost obtained by cutting off the cocks is poor economy.

Filter presses for corrosive liquors can be made of resistant metals if good castings, easily machined, can be made. The brittleness of high

silicon irons, the softness of hard lead and the excessive cost of illium prevent their use, but brass, bronze and aluminum are quite satisfactory. Happily, in most acid liquors encountered in filtration wood withstands the action fairly well.

Wooden plate and frame filter presses are the pivotal point in the manufacture of many materials including dyes. Their use insures freedom from metallic contamination and maintains color and purity of product. Wood presses are designed with less variety but with full adherence to the principles of operation.

Being weaker under compression strains than iron or other metals, wood presses are generally limited to a maximum working pressure seldom over forty pounds per square inch. Also, much greater thick-



Courtesy T. Shriver & Company

Fig. 34.—Wooden Plate and Frame Press.

For liquors corrosive to iron or cakes contaminated by iron rust, a wooden plate and frame press is particularly applicable. Mechanical strength is obtained by the proper selection of the wood used, by reinforcing tie rods, and by judiciously designing the thickness of both the plates and the frames. The gasket surfaces are usually greatly in excess of those required in metal presses.

nesses are required for width of plate or frame and wider surfaces are necessary to provide strength to carry washing conduits, etc. Rigidity is obtained by bracing with iron rods or exterior frames.

The biggest advance in wood presses has been in the drainage, for while the filtrate channeling by cutting grooves is all right while the press is new, it is a constant annoyance after being in service awhile as the pyramids soften, flatten out or break off. The simpler, cheaper and equally effective means is to fasten five layers of open hose duck or burlap to the plate. The openings in the successive layers of this material provide ample paths for the exit of the filtrate.

Many modifications of design have been devised, some for better washing and some for better discharge. Among the latter are the Merrill and Atkins-Shriver presses which are described under special filters.

To emulate pressure leaf filter washing has been the theme of those endeavoring to better filter press washing. The physical work of washing by displacement method is simple with plate and frame presses, but the attendant difficulties of poor drying effect, of difficulty of draining excess unfiltered liquor, and the greater difficulty of discharging the cake, nullify the advantage of the better washing obtained.

Operation.—Contrasting the operation of the plate and frame press with the industrial filters that preceded its introduction, we find it far less arduous work. Reflecting on the increase of production by means of the greater pressure, the vast area per unit floor space and the easier operation, it is natural that this machine was exceedingly popular.

Even today there are instances where its operating costs are less than those necessary with the more modern machines. Small capacity units, materials on which the cloths must be frequently changed or renewed, and for those materials on which the press is opened only at long intervals, are examples.

As is true of any other machine, if the filter press is operated correctly it is easy work and the team play possible when a crew of operators is required makes it interesting work.

Step number one is opening the ports and feed inlets. This is followed by laying the cloths. This, in the plate and frame type, is the simple folding of the cloth over the plate and centering the eyes over the conduit openings. In the recessed plate type one half of the cloth must be rolled up and fed through the feed eye. In either case it should be considered wilful negligence not to straighten out all the wrinkles or not to scrape off any adhering cake. A wrinkle or an obstruction is sure to be a point of leakage unless abnormal pressure is used in closing the press. The latter weakens the cloth at the wrinkle, so that in either case it is poor operation.

The press should be closed with as little pressure as possible. Straining on the closing device is significant of defective design or operation.

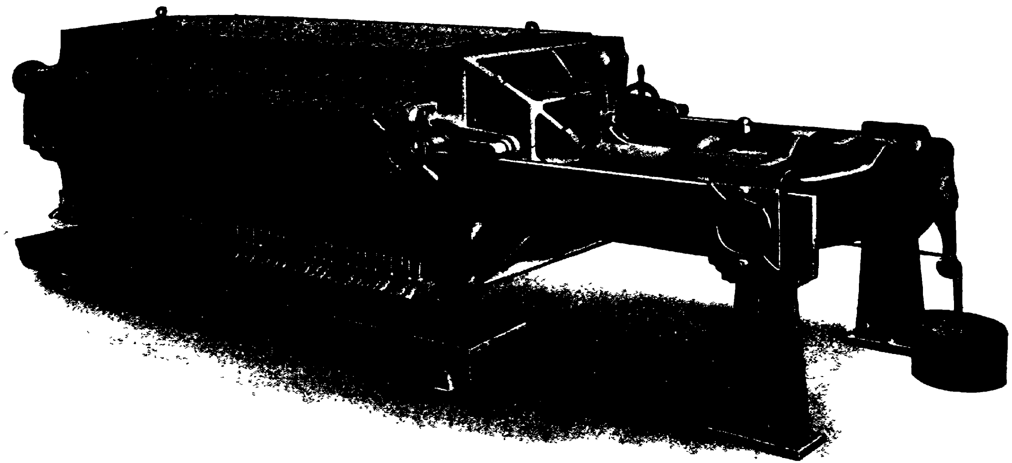
With the press closed, actual filtration can take place. With clean cloths it is generally the practice to open the feed valve and pay no attention to exhausting the air in the frames. The air leaks out through the cloth readily enough to let it escape that way.

Unless the pressure has to be regulated in excess of the regulation which occurs with the increase of pressure with decrease of flow, the operator needs but to make sure all plates are delivering clear liquor and then pass on to another press or job.

Filtration continues until the flow is practically stopped from all the plates. At this time the press is assumed full and all frames equally packed. If washing is desired the operator shuts off the feed line and every other outlet cock on the plates. The wash water is then admitted.

The limit of the washing cycle may be determined by sampling average filtrate until density is down to a given minimum, by taking samples of filtrate from end of frames and stopping when they have reached the allotted minimum or by working on a time basis.

After washing, most plants dewater the cake by compressed air or steam. To obviate the need of forcing the wash water in the washing plates through the cakes good operators open the cocks on these plates shutting them again when the air rushes out. Never should the plates be drained without the air line on, for the water can only release if replaced by air, and, if this is not provided purposely, it will be supplied



Courtesy T. Shriver & Company

FIG. 35.—Hydraulically Closed Plate and Frame Press.

A hydraulic cylinder is incorporated in standards of the press so that the piston is centered with the thrust block. The counterweights serve to bring the piston back into the cylinder when pressure is released in cylinder and press is to be opened.

from the caking chamber and disturb the cake formation. Such a displacement is sure to be followed by a short circuit when drying.

Blowing the press to dewater the cake operates to deliver both a drier cake and one more positively washed. The less the moisture content of the discharged cake, the less the soluble in the cake. It is seldom practical to attempt to wash the cakes to a fraction of one per cent in a plate and frame press. It is more economical to drop the soluble content to 5 or 10 per cent soluble, depending upon the material in hand. By "washing" is meant the added effect of washing and blowing operations. The discharged cake should then be re-puddled with weak wash water or fresh water and re-filtered. This second filtration is generally a simple matter, especially as the slurry can be confined to one high in solid content. By the double operation the residual solid in the cakes can be economically attained as low as $\frac{1}{10}$ of 1 per cent.

Blowing the press with steam is questionable practice for the condensation of steam means water in the cake. High temperatures shorten the life of the filter cloth. These are drawbacks but the main difficulty of steaming the press is this—*that the plates are too hot* for comfortable handling.

After blowing the press the locking mechanism is released and the movable head brought back to its extreme position. The press is now ready for discharging.

If the cakes are to be dried, pans or trays are slipped under a frame containing the cake and by tipping a frame, jerking it, or otherwise dislodging the cake, it lands in the tray and then is placed on trucks for drying. In handling small machines, some operators prefer lifting the frame with cake out of the press and depositing the cake on a tray placed on a table or across wooden horses. In either case, the idea is to rack the cake in its compact form.

If the cake is a waste product a hopper is located below the press and the cakes dumped into it. In such installations a lattice work over the hopper is a safety protection to the men and to the scroll conveyor in the hopper.

After the last cake is dropped, the plates and frames are reassembled against the stationary head. Now is the time that the efficient operator will make sure that his feed openings are all clear and his cloth unwrinkled on the gasket surface.

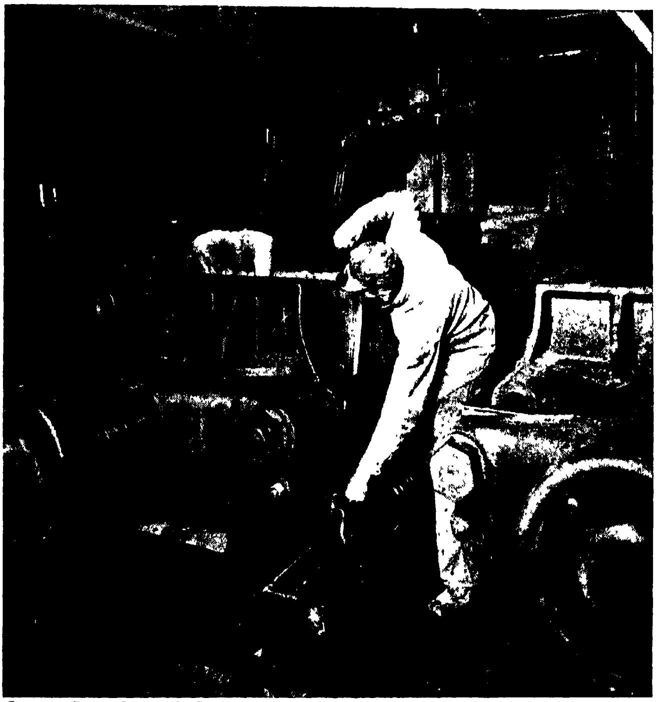
The operation of plate and frame presses is thus seen to be cyclic. Handling the press one or two times is generally sufficient to enable the average workman to master the job. There is no simultaneous shutting off of one valve and opening another, there is no nicety of timing. Discharging the cake takes place clearly before his eyes.

Layout.—The layout for a filter press is simple as compared with that necessary for more modern machines.

On setting up the press sufficient foundations are necessary. It is important that the side arms should be level. The reason for this lies in the fact that the closing device works at right angles to the face of the movable head. Each plate and frame as well as the movable head has a

normal position at right angles to the line of the closing pressure, that pressure will be distributed more evenly and result in quicker closing of the filter when the side arms are level.

Piping layout requires the three pressure lines, liquor, water and air brought to the stationary head and connected to their respective inlets with conveniently placed shut-off cocks. The filtrate trough, when using



Courtesy D. R. Sperry & Company

FIG. 36.—Characteristic Installation of Plate and Frame Press.

Accessibility to the filter cloth is a pronounced feature of plate and frame presses. Team work developed by the operators straightening and inspecting cloths is a simple job.

open delivery type machines, should be equipped with three outlets. One for cloudy filtrate, one for clear liquid and the other for wash water. Two cone plugs make the most convenient shut-off for such openings. It is also good practice to provide a hinged cover for the trough. Such a cover closes the trough when discharging the cake and prevents any spillage into the trough.

Closed outlet machines require more complicated layouts but the

installations of these in America are very special and in no sense standard practice.

Advantages.—The advantages of this type of filter were many when it was first introduced. At the present time its drawbacks weigh heavier than its advantages and its use is on a decline. It has, however, very positive advantages today and these merit consideration.

There is no industrial filter as simple as a plate and frame press. Its design and construction is so well standardized that it is familiar to practically every chemical operator. Its operation requires none of the nicety incident to the operation of pressure leaf filters or to the settling of continuous filters. Operators can be broken in and become competent with far less effort than necessary with the improved type of machines.

Any material can be handled in a plate and frame press. There may be more economical means of handling certain liquors but the plate and frame press is a safety first machine whenever a new process is installed, or whenever there are wide variations in the filtrability of a product, the reasons for which are obscure. Any material will build up a cake if sufficient time is given for filtration and a good hard cake is the only essential necessary for filter press operation.

Plate and frame presses can be designed for any pressure. In such work as extracting paraffin wax from oil distillate pressures beyond the limit practical for modern filters are used.

Accessibility to the filter surface is an advantage in any filter. In plate and frame filter presses the ease of inspection of the filter cloth is greater than in any other machine. Also, in no other machine is the work of replacing the filter cloth quite as simple and easy.

The work of preparing the filter cloth for the filter press is the least complicated of all the filters. No sewing of cloth, no binding down of the cloth with wire, and no permanent clamping of it between adjacent elements. The cloth is purchased by the roll, lengths are cut off sufficient to surround the plate and eyes punched in at the location of the feed, wash water, etc., conduits.

Acid liquors are filtered in wood presses with less contamination, corrosion and annoyance than in any of our modern filters. For this work plate presses are still supreme.

Drawbacks.—When handling large tonnages the labor cost for operating plate and frame presses is excessive. There are installations of modern filters which have been substituted for a previous installation of plate and frame presses where two men per shift are doing the work of nine men formerly needed. A daily production maintained by six men formerly taking 27 men is representative of the increased productivity per man obtainable with modern filters.

The filter cloth on plate and frame presses must be selected for its mechanical strength as well as its filtrability. This requires heavier and therefore less desirable filter fabrics. Also, the mechanical wear shortens the life of the cloth in filter presses, making the filter cloth renewals excessive in comparison with those necessary with modern filters. In one large plant $13,200.00 was the annual filter cloth expense with filter

presses as against a present cost of $1400.00. Costs differing like this are surely a drawback to filter presses.

Washing solubles from the cakes in filter presses is not a success. It is physically impractical to evenly and completely pack the chambers so that there are no short circuits. There always are paths of lesser resistance and the fact that more monetary savings have been effected by the better wash in modern filters than in any other saving made by them is proof that the washing method in plate and frame presses is poor. The principle of displacement wash is not practical in chamber presses and alternate plate wash is proven an inferior principle for washing.

The cycle of operations on chamber presses varies in proportion to the time necessary for cake building. If the cake deposition is slow it is necessary to continue at the slow rate until the press is full. This, therefore, means that there is lack of flexibility in this machine. This drawback becomes of vital importance when handling a product obtained from a crude ore, the gauge of which varies considerably.

Chemical plants are fast eliminating the stigma, so popularly fixed to them in the past, of being "dirty holes." The sloppy conditions so often prevailing around filter press stations has been corrected in numbers of plants by substituting non-leaking filters. Theoretically, such conditions should not obtain with plate press operation, practically, it does occur and only in the best operated stations is it reduced. Noisome conditions are proverbial with plate and frame installations and constitute a very valid drawback to their operation.

There are additional minor drawbacks which are pointed out in succeeding chapters. Specific mention of disadvantages is held to be good engineering for unless constructive criticism is constantly brought to bear, progress is arrested. Evidence of the value of such criticism is seen in the improvements in filter press design as developed by Merrill in his sluicing filter and the Atkins Brothers in their Atkins-Shriver self-discharge press. These machines are discussed in a succeeding chapter headed—Special Filters.

Applications.—For materials requiring subsequent drying the low moisture content in the cake makes plate and frame presses the preferred machines. For color work, especially where the same filter is used for different materials, no machine is as convenient as the plate and frame press. Wooden presses are free from the metallic contact always found in any other type of filter and, therefore, for materials requiring absence of metals it is the best machine. For new process and for materials as extremely contrary as raw cane sugar liquors, the filter press is the safe and sure filter.

Summary.—The greatest epoch marker in filter history is the filter press. Advancing from box and bag filters to high pressure, large area filter presses was the greatest boon to industrial chemical manufacture ever experienced in filtration. No greater memorial is possible than the fact that the filter press remained supreme for over a century. It might still be the leader were it not that American standards of living require

cheaper processes of production and greater productivity of labor. Labor saving was then the initial incentive for filter improvement and was first obtained by George Moore in his vacuum leaf filter, the first of our modern filters. Moore's work is, therefore, the subject of our next chapter.

Chapter IV.

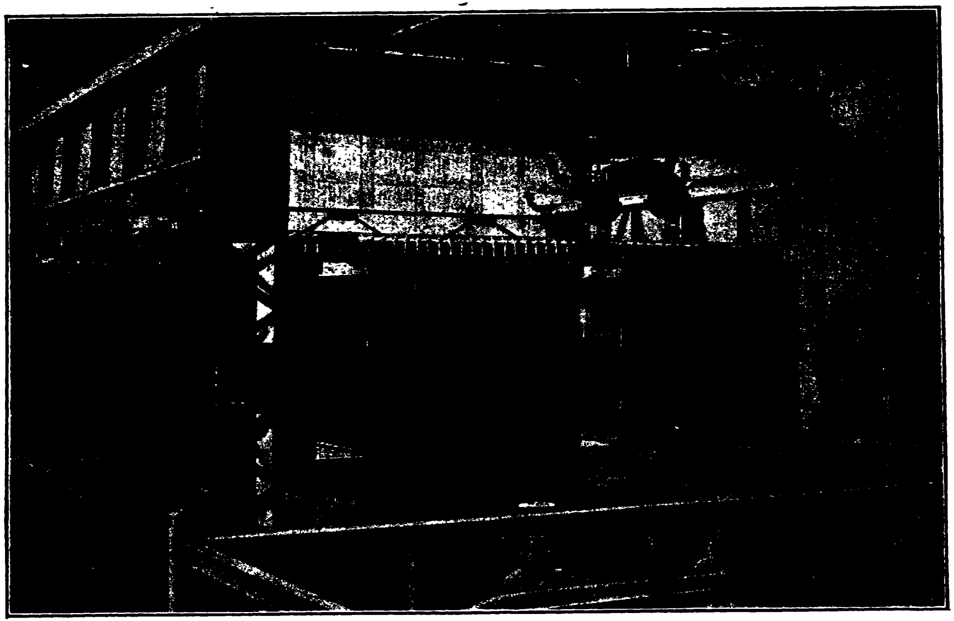
Suction Leaf Filters.

When the recovery of gold values received a big boon by the introduction of the cyanide process of dissolving the gold and silver present in ore, the mining industry as a whole was given an impetus such as has never been paralleled. All machinery involved in milling operations seemed to undergo a rapid transformation at that time to make them better. In the several processes necessary in the recovery of gold and silver from ore, filtration was the one that lagged most.

History.—At the time of the introduction of cyanidation of gold ores, plate and frame, or chamber, presses were the conventional machines for the filtering processes. The difficulties were that irrespective of the pressure employed, the solids were so slimy and fine that it took inordinately long to fill the frames with cake sufficient for anything approaching good washing results. In fact, filtration was "the neck of the bottle" in cyanidation, due to this trouble. Consequently when George Moore brought out his suction leaf filter, he opened up this throttle on the industry and made it the big success it has been for so many years.

George Moore, as a young graduate of Massachusetts Institute of Technology, went into the gold mining game via the assay chemist's laboratory. He climbed the ladder until he became superintendent of a mill which had started on high grade ore but soon had to handle a run of mine that assayed much lower. Soon after he took hold of the mill, the company went into receivership and the problem became acute,—could the mill be run at a profit on that quality of ore? As Moore saw it, the biggest costs and greatest losses were in extracting the gold values from the fines treated with cyanide. Moore scented a way out if he could build and handle thinner cakes. Instead of attempting any changes in his big Perrin plate and frame presses, he made a small square filter element with filter cloth on one side and an outlet pipe on the other. Putting suction on the plate and immersing it in a pail of slimes, he got encouragement right from the start which led him to perfect his process and his machine. In inventing this machine, Moore proved himself no dreamer. He was an observer of the first magnitude, and he capitalized his observations by working out his new filter with simple mechanics.

Development of the Scheme.—Moore's filter experience had been with plate and frame presses and he noted in their operation that until the cakes in any frame had joined together they were individual and separate deposits. If they could be washed and discharged independently,



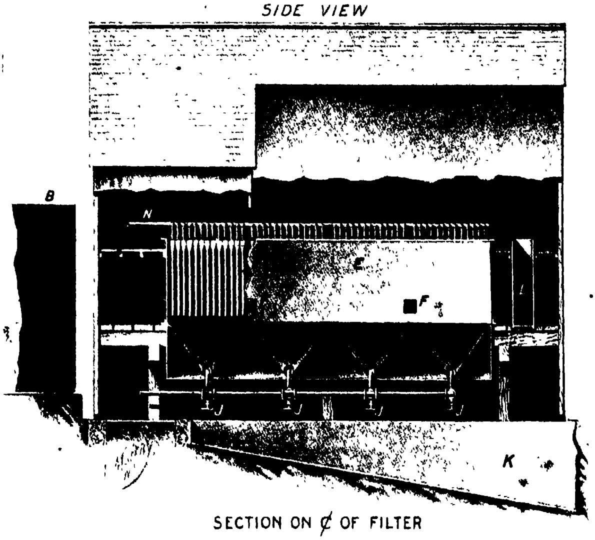
Courtesy Industrial Filtration Corporation

FIG. 37.—Moore Suction Leaf Filter.

The simplicity of the design of this filter makes possible filters containing thousands of square feet of filter area. Multiple baskets of large leaves carried on I beams and lifted by a crane make it convenient for one man to handle this tremendous filter area easily.

it would not be necessary to prolong the filtering cycle until the separate cakes did meet, but rather filtration could cease as the rate of flow became uneconomical. Again, being able to wash through one thickness of cake instead of two thicknesses would decrease the time for washing and in this way increase output.

Here, then, was his point of attack. He had in mind, also, bag filters in which the solids build up on the inside walls of the bag and are washed



Courtesy Industrial Filtration Corporation

Fig. 38.—Moore Stationary Leaf Type Filter—Better Known as Butters Filter. Instead of moving the leaves from a liquor tank to a wash water tank and to a discharge hopper, the leaves remain stationary and the liquor is drained from the tank, wash water is pumped into the tank and, before discharging, is drained from the tank. The washed solids are sluiced from the tank as a fluid mixture.

through one thickness of cake. If he could get away from the tremendous work of cleaning the bags, this would be the solution. How rational, therefore, to make the cake deposit on the *outside* of the bag instead of on the inside, so that a reverse current would disengage the cake from the filter medium and thus effect its discharge. He therefore enlarged on the laboratory Buchner funnel by applying suction power to the interior of the bags.

In brief, this summarizes the work of Moore that led to his originating the *suction leaf filter*. His discovery made practical the handling of ore slimes, the treatment of low grade ores, and the re-treatment of slime piles, for the first time in history.

Launching a company for the exploitation of his patents was one exasperating trial after another. Intra-company dissensions marred what should have been one of the greatest propositions of the time. Over a period of years, the energies of the company were directed toward control of the company rather than the exploitation of the scheme, so that the Butters, Ltd., a consulting engineering concern of prominence, were quick to take advantage of a variation of the Moore idea.

The Butters Filter.—The filter known in the industries as the Butters Filter was devised by a Mr. Cassel who was at one time associated with Mr. Moore in the early development of the Moore filter. The Cassel patent was assigned to the Butters company and exploited by them under their own name. This machine, now obsolete because of its infringement of the Moore patents, was fundamentally identical with the Moore filter, but in operation the Moore filter leaves are transferable from the liquor to the wash waters, while the Butters leaves remained stationary and the liquor and wash waters were successively pumped into and drained from the one tank. This was the only difference between the two machines. In the Butters filter it was not feasible to obtain dry discharge, as the cakes fell off into the hopper bottom of the tank and were there puddled to a slurry and pumped to waste. It is indeed curious that one should put out a machine as original and new on the sole basis that, though identical with a patented machine in all other respects, its leaves were stationary instead of movable! The Butters filters was a cheaper machine to install, since its tank requirements were one instead of several and no crane was needed to transfer the leaves. It offered, however, the disadvantages of not being fool-proof so that instances occurred where valuable gold solutions were pumped to waste dumps; leaky valves enriched the wash solutions, and dry discharge was never practiced.

Aggressive exploitation of this machine, however, netted the expected results. Claiming infringement, Moore started litigation.

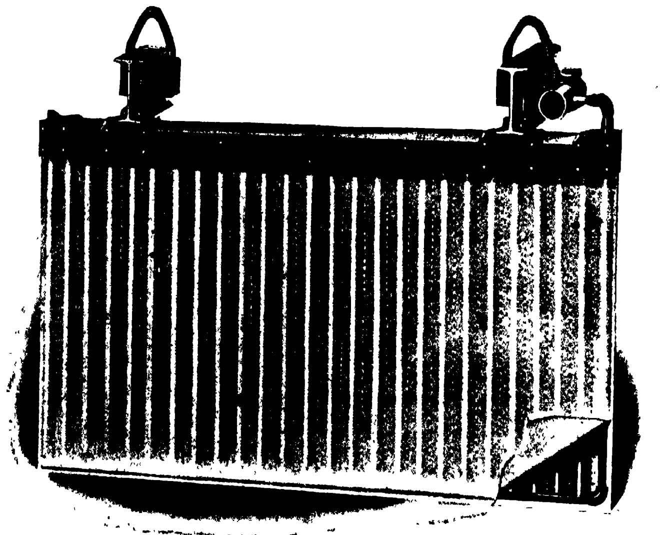
Importance of Court Decision in Moore vs. Butters.

Butters won out in the lower courts, but on appeal the Moore claim was upheld. On delivering this decision, the Court made a point which is of importance not only to filtration but to every inventor at large. It was defined that:

> *whenever a discovery is made of something already existing in everyday operation and put into new use whereby industry is benefited* so as to increase its resources and output, that discoverer is *entitled to patent protection.*

This decision sets at rest any argument that equi-resistant cakes have always been and always are formed in plate and frame presses prior to the joining together of the cakes, and that therefore Moore made no invention. In his *process,* Moore was a *discoverer,* in the *mechanics of his machine,* Moore was an *inventor,* and his contribution to filtration will ever stand as monumental.

The claim which is the essence of the Moore process and on which the suit was won is: "The process of filtering slimes and the like consisting in immersing filter in a bath containing slimes and a fluid in which they are suspended, forcing said fluid through said filter by difference of pressure between opposite sides thereof, whereby slimes are deposited thereon in a layer of requisite character, removing said filter from said bath while maintaining a superior pressure on outside thereof, intro-



Courtesy Industrial Filtration Corporation

FIG. 39.—Moore Filter Leaf.

The design is founded on the prevention of the filter cloth collapsing so as to have free drainage when suction is applied to the leaf. Wooden sticks threaded into pockets between vertical rows of stitching provide ample drainage from many liquors. The frame is made of perforated pipe terminating in the outlet pipe. The top of the leaf is clamped between wooden bars which are attached to I beams from which each leaf is individually suspended.

ducing same into another bath and impoverishing the slimes by forcing another fluid therethrough as aforesaid, removing filter from said bath and subsequently cleaning it by air pressure applied to the back of said filter."

Design of the Suction Leaf Filter.

The principle of the Moore leaf design is that a bag of filtering medium shall envelop a drainage member having an outlet. The function of the drainage member is to prevent collapse of the bag and to provide channels for passage of the filtrate to the outlet. Collapse of the bag

tends to occur whenever there is a difference in pressure between the outside and inside of the bag, but is prevented by the drainage member which can be made of cocoa matting, or corrugated or grooved wooden slats, or of crimped wire screen, etc. Note, therefore, that the filter cloth has to be internally supported whether used for Moore's suction filter or for any of our present day pressure leaf filters.

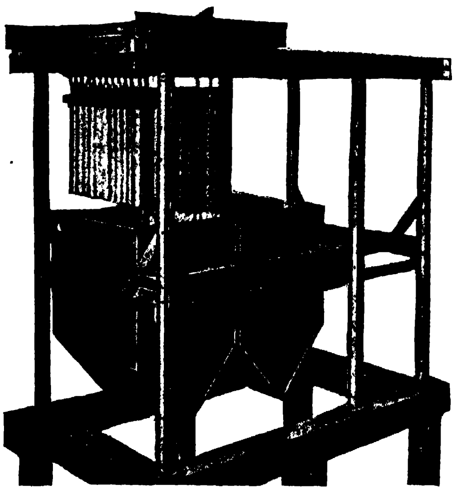
In practice, the frame is rectangular and is made of fabricated and perforated pipe. The drainage member is either corrugated screen secured to the frame or formed by wooden slats slipped into pockets sewed in the bag. These pockets are formed of vertical rows of stitching spaced approximately two inches apart.

The suction leaf filter as used in mining plants and the chemical industry consists of a number of individual leaves hung from a frame to form a basket, successively immersed in a series of open tanks filled with the muddy liquor, weak liquor wash and wash water respectively. A manifold pipe connects each leaf with a common source of vacuum pressure or a source of compressed air which is used in discharging the cake. The filter leaves are spaced 4 or more inches apart, depending upon the cake thickness to be built up, and are made in sizes from 2 ft. x 3 ft. to 8 ft. x 10 ft., or greater. It is practical to design these filters with surface areas of 10,000 sq. ft. Each leaf is hung from I beams, or similar supporting frames, and is rigidly held in alignment. The outlet from each leaf may connect with one or two manifold pipes, the latter also being securely fixed to the frame. The connections from the manifold pipes to the filtrate receiving tanks must be flexible hose of a length to carry to the farthest tank. The vacuum is produced by a dry vacuum pump exhausting from receiving tanks and the filtrate is removed from them by means of a barometric leg, centrifugal or other types of pumps. Wet vacuum pumps, unless of the Nash Hytor design, do not have sufficient air capacity to make them practical for this work.

The leaves, source of suction, and the open tanks are the essential equipment for suction leaf filters, but convenient means of transporting the leaves from tank to tank is equally essential when handling large tonnages. Assuming a cake deposit of only 3 lbs. per sq. ft. of surface, a filter with 667 sq. ft. has a load of a ton of cake in excess of the weight of the leaves and frame. The weight of the latter varies, depending upon the construction, but the load to be handled will range from ½ ton to 18 tons. so that the crane or hoist employed is a sturdy affair. The leaves must move up and down, as nearly vertically as possible, and with minimum swaying, or else cake will be dislodged. It is a simple matter to move a single leaf with cake so long as the suction pressure is maintained within the leaf. This pressure holds the cake to the filter cloth and prevents discharge of the cake, but in a large practical unit even though the suction pressure is correctly maintained the hazard of partial discharge of the cakes is greater, due to the greater load of cake, and the possibility of jarring the leaves when transporting them. For this reason the pick-up by the crane is always from a 4-point suspension with the length of chain gauged so that the crane pulls directly over the center of gravity. Sway-

ing is obviously dangerous for the reason pointed above, and abrupt stopping is equally bad, either in the vertical rise or in moving horizontally over one tank to the next position. Some of the crane manufacturers therefore developed special cranes for this purpose which proved quite efficient as long as the operator exercised reasonable care.

The tanks for these filters are rectangular with sloping or cone bottoms, and are best when provided with some means of agitation. This can either be by means of perforated pipes through which compressed



Courtesy Industrial Filtration Corporation

FIG. 40.—Experimental Moore Filter.

The application of a leaf filter can be determined by the results obtained with a single leaf, but the plant operation is best determined by a small machine complete with its crane, tanks, etc.

air is fed, so that the liquor is maintained at an even density by the uprising air bubbles, or a circulating pump can be used forcing the liquor in at the bottom and overflowing at the top, or vice versa.

One of the main essentials for operating efficiency is that the liquor level in the tanks shall never fall below the top of the leaves. If all the leaves are not fully submerged all of the time, cake thickness, and permeability of cake to wash water, will vary and consequently defeat the first principle of the Moore leaf design. Constant submersion is best obtained by constant liquor level. There is no simpler means of providing this than to have an overflow connection at the desired liquor level and always feed into the tank more than the filter leaves exhaust from the tank, so that there is some overflow all the time.

Operation.

The operation of suction leaf, and pressure leaf filters, is cyclic in nature, so that the operation works on a schedule of leaf transfer and valve manipulation. None of the work is laborious, and all of it is so simple that the operation of any one filter takes but a part of one man's time. The number of filters one operator can handle depends upon the length of the several cycles. For instance, if the filtration is ½ hour only, the weak liquor wash 20 minutes; the water wash 15 minutes; and the discharge 12 minutes; the intervals of the latter operations are too short to warrant attempting to operate one more unit. If, on the other hand, filtration takes 2 hours; weak liquor wash 1 hour; water wash 45 minutes; and discharge 12 minutes, one operator can conveniently handle at least 3 units and not be overworked.

The initial operation is lowering the leaves into position in the filtering tank and filling the tank with muddy liquor. As soon as the operator turns on the vacuum connection, filtration commences. Preferably the operator should know in advance how long filtration should continue before starting the washing operation. This information may be gained by previous experiment or by data supplied by making previous experimental runs on the material in hand. If this information is lacking, the operator must watch the filtrate flow. This will constantly decrease in volume, unless the vacuum pressure is low at the start, due to the dry vacuum pump or centrifugal exhausting pump being too small to exhaust fast enough the volume of filtrate flow obtained at the start of filtration. In this case the vacuum pressure will rise while the flow remains constant until a maximum pressure is reached, when the flow will start to fall off. Noting the decrease in flow can serve only as a guide as to when washing should commence, for the prime consideration is that there shall be sufficient cake on the cloths to be easily discharged. Cakes ⅛ in. thick are too thin for automatic discharge by reverse currents, since the air will blow out through small patches and will not disengage the bulk of the cake from the filter leaves. A minimum cake thickness should be ⅜ in. and even this is small with materials of low specific gravity. If the material in hand is relatively free-filtering so that cakes greater than ⅜ in. can be built up, the operator can be guided by the filtrate flow. What constitutes the economical limit depends in a large degree upon the succeeding operation. If washing is not necessary the flow can drop off to a much lower limit than if the cakes must be washed, for then the flow must be great enough to get the wash liquor through in a reasonable time. In many applications the flow on washing increases due to the decreasing gravity of the entrained liquor in the voids of the cake. In consequence, the flow at the end of the filtration is a minimum flow for the entire cycle, and, with this in mind, the limit of filtration can be gauged accordingly.

Washing.

To change from filtration to washing is simply to transfer the leaves from the filtration tank to the wash liquor tank. This is wholly a matter

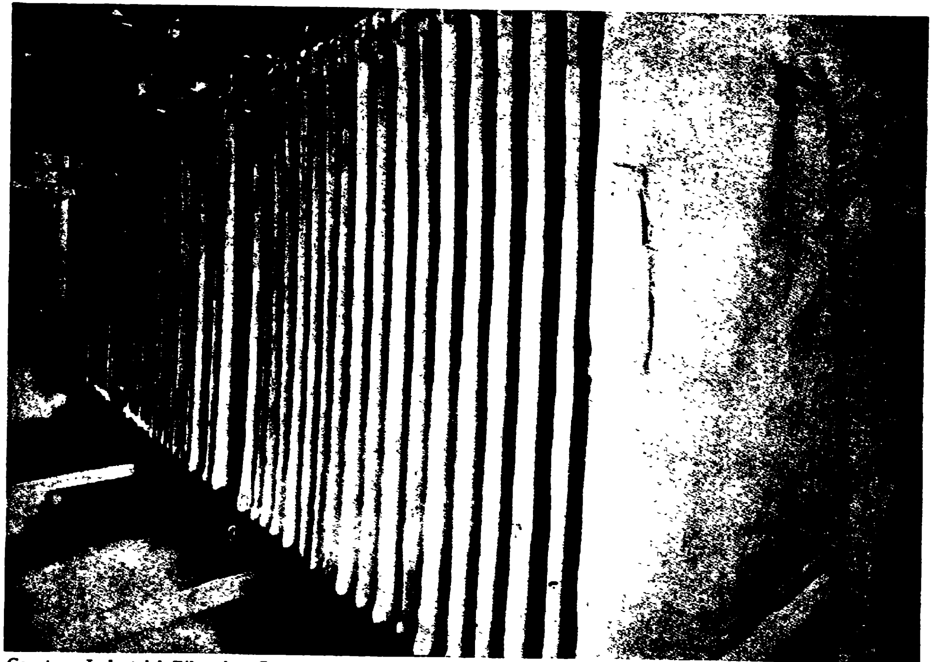
of operating the crane or hoist in order to lift the leaves out of the slurry and drop them into the wash tank. If this transfer is conveniently and quickly done, the vacuum supply is not changed but maintained at the limit reached by the end of the filtering cycle. If the transfer takes longer than 5 minutes it is best to reduce the vacuum pressure to a lower limit (10 to 15 in. mercury).

Washing continues until the filtrate reaches the desired specific gravity. If the first wash is a weak liquor, this point will be somewhat in excess of the specific gravity of this weak liquor and is determined in relation to the plant requirements. Where evaporation can be lessened by mixing the first strong wash filtrate with the original strong filtrate this limit will be higher than is the practice in mining work. Here the intermediate wash liquor is barren cyanide solution, this being the equivalent of a mother liquor in chemical plant operations and is the cyanide solution from which all the precious metals (gold and silver) have been extracted. The object of the barren solution wash is to regain the valuable gold and silver cyanides in the minimum dilution, and, by using barren cyanide solution, the strength of the cyanide is maintained. The succeeding wash with water is in order to recover the cyanide, the weakened strength of which is brought up by adding fresh material, or by concentration. The final wash filtrate should approach actual water and if the washing has been efficient the volume obtained should not be excessive.

Drying.

Washing the cakes is generally followed by drying them. The term "drying" is largely a misnomer as 35 per cent moisture is a low limit for dryness of cake obtained with this type of machine and "dewatering" would seem to be more explanatory. Even if the discharged cakes are to be mixed with water and pumped to waste dumps so that the moisture content is of no moment as such, it is of value to dewater since imperfect washing is bettered when the least moisture remains in the cakes.

Drying consists simply in raising the leaves out of the water tanks and pulling the atmospheric air through the deposited cakes. Depending upon the class of material in hand the cakes will become dry enough to become pitted with openings or honeycombed with cracks through which the air short circuits, decreasing the pressure at which the vacuum pump can handle the volume of the air. It is waste energy to continue drying after the vacuum pressure has dropped under 50 per cent of the limiting pressure maintained during the washing operation. The gain in decreased moisture content is slight and pumping the big volume of air through the dry vacuum pump takes power far out-balancing the moisture reduction. The drying operation will vary from 5 to 20 minutes depending upon the material and cake thickness. Leaves that drain from the bottom will exhaust more of the entrained filtrate than those that have the outlet at the top. Draining from the bottom is usually obtained by perforating the bottom pipe of the filter frame so that all of the filtrate is collected at the bottom and sucked up through the frame.



Courtesy Industrial Filtration Corporation

FIG. 41.—Ready for Discharging.

With each square inch of filter cloth loaded with a cake of ½ inch or more thickness, weighing two pounds per square foot, it is easy to understand that these machines can handle tons of solid per cycle.

Discharging.

The drying operation usually takes place while the leaves are in position over the discharge hopper. Consequently, to change from drying to discharging is simply a matter of shutting off the suction connection.

Discharging is effected by one of a number of methods: reverse current of compressed air; steam blow-back; by combining either of the above with hosing off the cake; or by submerging the leaves and then by using either of the above reverse currents or reverse current of water.

Reverse compressed air is most generally used. This is done by connecting the compressed air with the filtrate manifold, the air penetrating through the filter cloth on each leaf from the inside of the leaf. As the air pushes against the cake, it lifts the cake away from the surface of the cloth, so that gravity makes it fall. It is often necessary to turn on the compressed air alternately as tenacious cakes are seldom dislodged with one rush of air. Again, some parts of the cake will often hang up indefinitely and rather than prolong the time and waste of compressed air, a long paddle is used to disengage these. This brings hand labor into the operation and while not strenuous, is not strictly automatic discharge and takes time. Badly cracked cakes discharge less readily than uncracked cakes and if the material being handled is at best difficult to disengage from the cloth,—drying must be shortened to prevent cracking and leave as much mass weight to the cake as possible.

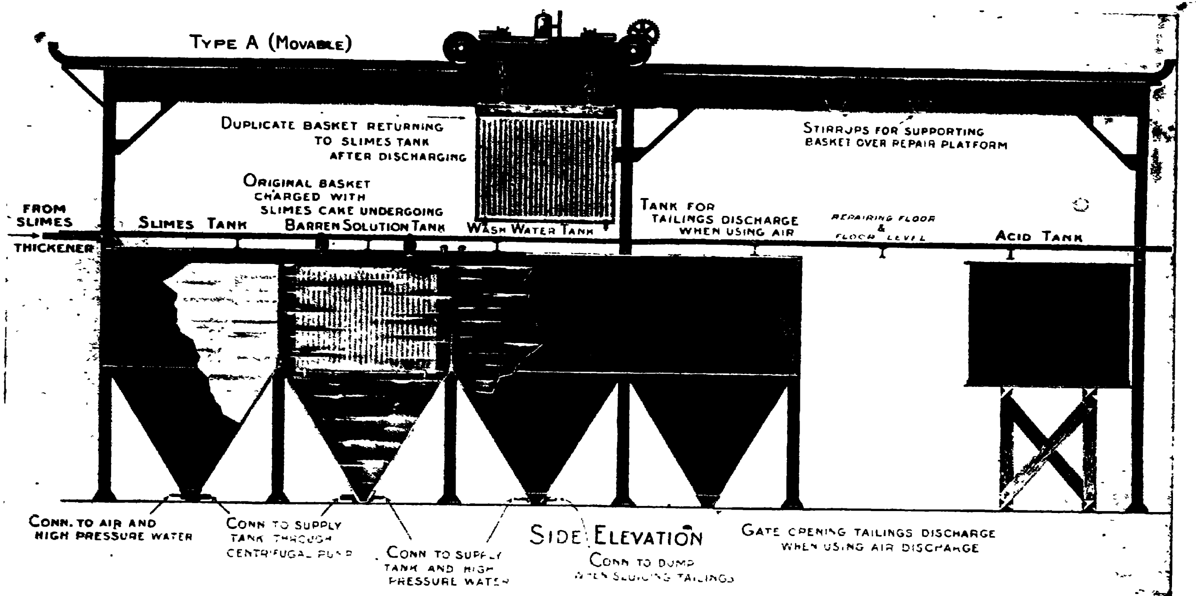
Steam is never used unless compressed air is ineffective and its use must be guarded lest its high temperature weaken the filter cloth. In either case, of steam or compressed air, the pressure must be limited so that the cloths will not burst and a safe pressure is under 10 lbs. per sq. in. Reverse water or reverse compressed air, while the leaves are submerged, is often effective in dislodging thin cakes, but this method will be seldom found in practice today as such materials should be handled in different machines.

Advantages.—The outstanding advantage of the suction leaf filter is the high washing efficiency obtainable by displacement wash, and while there are other advantages of note this is undoubtedly the factor on which most of its installations were made.

The most spectacular advantage is the reduction of labor necessary in the operation of these filters. Often one man can do the work of ten necessary in plate and frame filter presses and with less energy than is expended by any one of the ten.

An operating advantage making for high capacity and economy is the ability to shut off filtration as soon as the economical cake thickness has been reached, rather than having to continue filtration at a low rate of flow until the cake is compacted, as in plate and frame discharge.

An economical advantage lies in the fact that filter cloth is not subjected to mechanical injury and wear, by being used as the gasket between abutting plates and frames or in handling it and washing it in tumbling washing-machines, so that the life of the cloth is much lengthened over bag filters or plate and frame operation. This factor makes possible the



Courtesy Industrial Filtration Corporation

FIG. 42.—Layout of Moore Filter.

In addition to the tanks, crane, feed and drain lines, vacuum pumps, receivers, and filtrate exhaust mechanisms are required.

use of thinner fabrics and means that there can be a choice of filter cloth for a particular material.

The piping layout and valve manipulation is a minimum with this type of filter, especially if the barometric leg is used for the removal of the filtrate from the receivers.

Suction leaf filters were, when first developed, the finest filter obtainable, but improvements in continuous filters and in pressure leaf filters have decreased their importance to a large extent. Today, suction leaf filters stand out as economical in the first cost whenever huge tonnages must be handled, since their construction is so simple as to allow large areas to be operated in one machine. Also, the simple construction makes it possible to protect these machines against acid attack. Whenever lead is the only permissible metal to be used, these filters are in a class by themselves. Many installations have been made wherein the collecting pipes are made of lead, or are lead-covered; the filtrate manifolds are lead and the receiving tanks lead-lined or wooden; the drainage member made of wooden slats and the filter cloth of wool or other acid-resisting material. In any other type of machine there are wearing parts or heavy castings requiring lead lining which have proved costly in maintenance.

The acid-proof suction leaf filter has only one filter competitor, i.e., the wooden plate and frame press, but where applicable the suction leaf filter is preferable.

Drawbacks.—One of the early disadvantages of this type of machine was the limitation of the filtering force, i.e., atmospheric pressure. At sea level this pressure can be utilized nearly to its maximum of 14.7 lbs. per sq. in. (or 30 in. of mercury). In higher altitudes there is a drop often amounting to as much as 25 per cent of that obtainable at sea level. These low pressures often require excessive filter area in comparison with machines capable of working at 50 to 60 lbs. per sq. in. Large areas mean large filter leaves which are cumbersome to handle and to re-cover.

Applications.—More of these machines have been installed in the mining industry than in any other. Ability to handle large tonnages per cycle made them especially adaptable to this work. With the advance of automatic and continuous decantation systems, by which the solids to be filtered are concentrated in smaller volumes of liquids, continuous filters have taken their place.

In chemical plants the tonnages to be treated per day are far less than in the mining field and here pressure leaf filters are preferred.

The acid-proofed filter is, however, a most practical unit for acid filtrations in which wool or other fabric can be used. It offers by far the best proposition wherever an exacting wash is required and automatic discharge is desirable.

Summary.—In summing up the development of filters as outlined thus far we see first: that the crudeness of the bag filters paved the way for the long reign of the filter presses (nearly 100 years); secondly: filter presses were almost entirely limited to products running up to a maximum of 100 tons a day. But, while the labor involved in their operation, the inefficient washing of cakes and high filter cloth consumption were draw-

backs, it was not until the introduction of cyanidation with its requirements of handling several hundreds of tons per day, as well as exact washing of the cakes, that there was felt a decided need for a better filter. This brought on, thirdly: the development of the suction leaf filter with its characteristic high washing efficiency and its advantage of low labor and small filter cloth maintenance cost. Weakness in handling hot liquors, and the limitation of atmospheric pressure as the maximum filtering force, predestined it to give way to the pressure leaf filter, which is next described.

Chapter V.

Pressure Leaf Filters.

Pressure leaf filters comprise a type of modern filter familiarly known as the "filter press." This is, however, a misnomer, since they do not do any pressing of the cake as is the practice in the hydraulic presses used to squeeze oils from seeds, like cotton or flax seed, or to squeeze juices from fruit as in the case of grape juice. They do not even press the cake by the compression of filtration as in the operation of plate and frame filter presses. They are simply filters in which the filtering force is greater than atmospheric pressure, supplied by pump, gravity head, etc., and in which the filtering elements are filter leaves in principle exactly like suction filter leaves. In lay language, the liquor is drawn or sucked through the leaf by vacuum in a suction leaf filter, and in a pressure leaf filter it is forced through by pump.

The three most prominent filters of the pressure type are:

The Kelly
The Sweetland
The Vallez.

The first two were developed at about the same time, although the Kelly first appeared on the market. The inventor of each of these machines was thoroughly familiar with the suction leaf filters and their operation and in each case was prompted by the same desire,—to increase the filtering force above that of atmospheric pressure,—pursuit of which led to the respective filters. The Vallez filter is a later development designed to overcome some disadvantages found with both of the others in beet sugar work.

While increased force of filtration dominated the reasons for developing pressure leaf filters, other reasons well demand their use. When handling liquors heated close to the boiling point at atmospheric pressure, suction filters are generally inapplicable, since under reduced pressure ebullition is induced and the vapor produced either adds a duty on the vacuum pump or must be condensed by condensers of the surface or jet type. Such auxiliaries complicate filter operation beyond practical limits. Again, when handling hot supersaturated liquors, pressures above atmospheric pressure are above the critical pressure at which crystallization or precipitation starts, but reduced pressures corresponding to 20 in. of mercury almost always induce rapid deposition of the crystals blocking up pipe lines, drainage members, etc. Consequently, in chemical plants

these pressure leaf filters are far more popular and numerous than suction leaf filters.

"Pressure leaf filter" is quite descriptive in itself of this type of machine. It is a filter in which leaves are encased in a container capable of withstanding internal pressure, the outlets of the leaves extending through the casing and open to atmospheric pressure. Filtration is obtained by feeding the muddy liquor into the shell or casing at a pressure in excess of atmospheric, when the filtrate drains out at atmospheric pressure.

There have been instances where the outlets did not drain to the atmosphere but were linked up to suction receivers. Such practice is time-worn as the only advantage gained was the additional filtering force obtained. This effect is more simply obtained by increasing the pressure of the pump. Where gravity feed pressure is inadequate, the only possible excuse for using suction is where the muddy liquor scours the pump and where clear filtrate is easily pumped. Such cases are too few for consideration.

The three prominent filters of this type vary only in mechanical construction, as each of them employs the same principles of operation as obtained in suction leaf filters. The mechanics employed in each are, however, ingenious in themselves, and differ widely from one another. They can be designated and differentiated quite positively by the design of leaf used in each case. The Kelly filter employs a rectangular movable leaf; the Sweetland, a circular, stationary leaf, and the Vallez, a rotary circular leaf.

These will be discussed in succeeding chapters in order of their appearance on the market. Sufficient details of construction will be included to acquaint the reader thoroughly not only with the design of these machines but with the principles underlying the design. No attempt will be made to carry description to a point of discussion covering strength of material, choice of materials of construction to withstand corrosion, etc., information on which is specific for a particular material and best obtained from manufacturers' catalogues.

Chapter V.

Section I—The Kelly Filter.

The Kelly filter was one of the early modern filters, and the first of the pressure leaf filters to come into the market. It is best described as a shell containing filter leaves locked in a closed pressure cylinder, one end of which unlocks and slides along from the cylinder carrying the filter leaves with it. The most distinctive features of the Kelly filter are that:

(1) All the leaves are rectangular, and
(2) parallel to each other and to the longitudinal axis of the cylinder, and
(3) leaves are carried outside the machine before the cake is discharged from them.

History.—The Kelly Filter was invented and developed by David J. Kelly of Salt Lake City, Utah, and appeared first in 1907. Kelly had been associated with George Moore in his work with vacuum filters but was dissatisfied with the limitations of vacuum as the working pressure for filtration. He was most impressed with this shortcoming when working with a vacuum installation at a gold mine located at a high altitude where the maximum pressure developed was only 20 in. or 10 lbs. per sq. in. If he could encase the leaves in a container capable of withstanding internal pressure he could force the liquor through the filter cloth by pump pressure and work at 50 lbs. per sq. in. The ore he was working on at that time was particularly amenable to an increased filtering force and his early work resulted in the right encouragement to increase his enthusiasm to continue the work.

Development.—It is well to note that Kelly in his filter sought to, and did, maintain all the advantages of vacuum leaf filters, but with the increased capacity could eliminate the tremendous area necessary in the vacuum installations. In addition to the obvious advantages of greater filtering force, there is the ability to handle boiling hot liquors without providing for the condensation of large volumes of steam. These factors make Kelly's contribution to the advance of filtration truly prominent and entitled to just recognition. In his filter he sacrificed none of the advantages of leaf filtration, although accessibility to the filter leaves and ease of observation of cake building would seem to be somewhat lessened.

Design.—The starting point of the design of the Kelly filter is probably the filter leaf. These filter leaves do not differ in essential principle

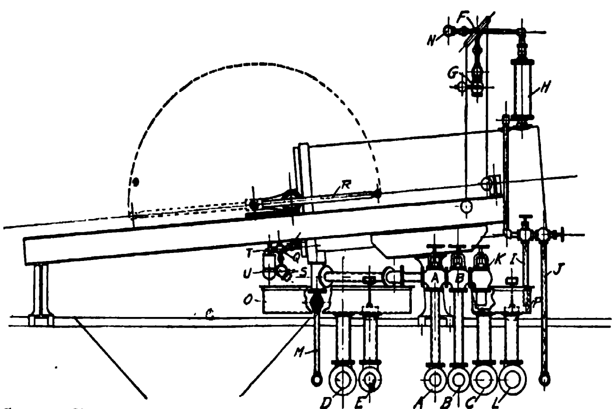
from vacuum filter leaves employed in suction filters. Kelly did work some modifications in mechanical details and materials of construction, but these can be best dealt with later.

The outstanding point in the design of Kelly filters is the locking device. Any one starting in on a work as Kelly did, would naturally employ a cylindrical container to withstand internal pressure. The next point is one at which considerable difference would arise: how to open the cylinder in order to discharge the solids from the filter leaf? Notice that if the cylinder were placed vertically with a removable top head, such that the leaves could be drawn upward and out of the tank, double head room would be necessary and a traveling crane required, quite similar to that used in the Moore filter. If the cylinder were placed horizontally, with one end open, then the leaves must be carried on a supporting frame capable of rolling out from the shell. Friction plays a big part, for the leaves are loaded with the weight of deposited cake when the leaves are to be discharged, and this load, of course, increases the friction. In consequence, Kelly placed the cylinder on an incline so that gravity would assist in overcoming this frictional resistance.

Having thus defined the placing of the cylinder, at the same time Kelly defined that it would be open at one end only and the locking and unlocking of this is the interesting feature of his early work.

Locking Device.—In closing the head of the cylinder, hand swing bolts readily suggest themselves as the simplest means of locking the head to form a water-tight joint. The number required increases with increased diameter, and the labor required is likewise increased. Modern filters are, however, distinctly labor savers, and such hand labor, therefore, could not be permitted. One is struck with the genius and simplicity of the idea of adopting the mechanics, familiar to all of us in opening an umbrella, to supplant these swing bolts. Kelly's locking mechanism is therefore refined umbrella-opening. U-bolts are secured to the shell and are of such a length that when the radial arms on the movable head engage them they bind on an inclined surface until the head is secured to the shell. These radial arms are analogous to the spokes of an umbrella and are actuated by a revolvable shaft through a toggle arrangement, so that small pressure applied to the rotation of the shaft exerts a greatly magnified pressure on the radial arms. This scheme of closing has been maintained to the present day, and in the smaller units requires a simple turning of the lever handle shown at R in Fig. 43 through 180° to the position shown dotted. The shaft is clearly shown at right angles to the fixed central shaft carrying the radial locking arms and a bearing through which the revolvable shaft extends. The toggles are secured to the revolving shaft and the movement of the shaft through the toggles propels the locking arms along the central shaft. The outer ends of the arms rest on the rim of the movable head, and this inward motion propels the arms radially when they engage the U-bolts. The reverse operation brings the radial arms out of engagement with the U-bolts and unlocks the head. The lever handle operation is supplemented by either automatic hand head locker or air operated device, both of which operate through

sprockets and chains which are shown attached to the rigid cross member in Fig. 44. This member is shown as two pieces of flat iron expanded at the center so as to surround the central shaft. At the ends it is connected by two links to the carriage carrying the filter leaves. When the leaves are in their discharging position, these links are extended to lie in a straight line so that when the filter is to be closed the chains, pulling on the cross member through the links, push upon the carriage. When the filter is closed and ready for locking, the links have engaged lugs at the side of the shell and are thrown out of the straight line into a broken line position. A further pull on the cross member now acts on the ring



Courtesy United Filters Corporation

FIG. 43.—Kelly Filter—Layout Showing Filter in Locked Position.

Note that the lever R, which is the locking lever, needs but to be rotated 180° to the dotted position to fully unlock the filter preparatory to withdrawing the leaves to discharge the cake.

connected to the radial arms. As this ring moves inward the arms move outward. Obviously, this scheme of locking duplicates that which we have discussed in the hand-operated scheme.

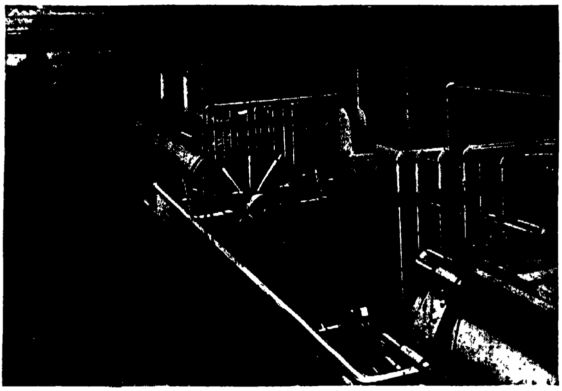
When operating the twin unit the variation from this is simply that a long steel flat is substituted for part of the chain and slots are provided in it so that a pin may be dropped in which will operate one filter or operate the other.

If the locking mechanism on the Kelly filter is the most striking part of its design, there are other individual features in this machine that merit attention:

(1) the automatic air-regulating device which is, in effect, a provision for positive pressure within the filter when the machine is in operation;
(2) the disposition of the leaves to give the maximum area;

(3) the tandem, or twin, arrangement whereby two filters are placed facing each other, thereby reducing floor space required; and,
(4) filtrate outlet connections with provisions for reversed compressed air for discharge.

Air-Regulator.—The need of positive pressure on the cakes during draining of excess liquor was the incentive that led to the development of the air regulator. It is founded on the motion of a rising or falling float riding on the liquor in the filter. When the filter is operating on the clarification, or washing, cycle the liquor enters the air chamber and



Courtesy United Filters Corporation

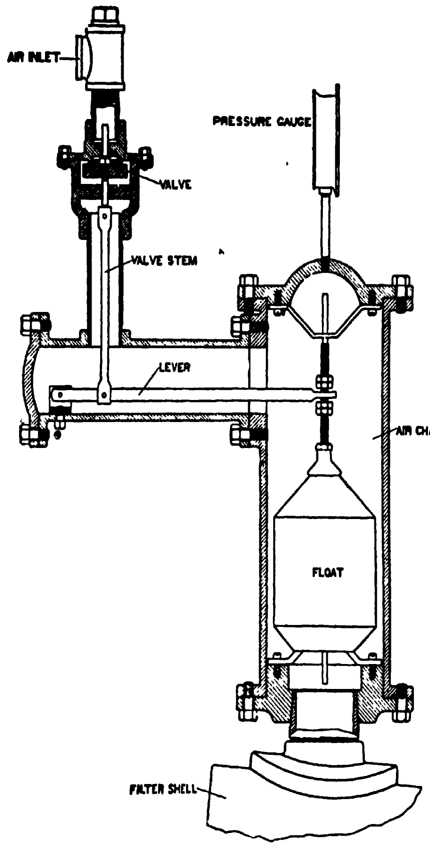
FIG. 44.—Typical Installation of Twin Unit Kelly Filters.

The two filters face each other with sufficient space between them for the leaves of one filter to be discharged at a time. The hopper is located under the floor with side boards extending above the floor. This is the economical use of floor space for installing Kelly Filters.

lifts the float to a high position. Here the lever has pushed the valve upward, closed the valve and cut off the compressed air. When the liquor is being drained from the filter the float falls to its low position, when the lever pulls down on the valve stem and opens up the compressed air to hold the cakes in place.

The automatic introduction of compressed air and automatic shut-off, reduced the possibility of the operator's letting the pressure off on the filter while draining. It is unnecessary, however, where trained workmen operate these machines, and its interest lies more in the simple mechanics of the device than in its operating advantages.

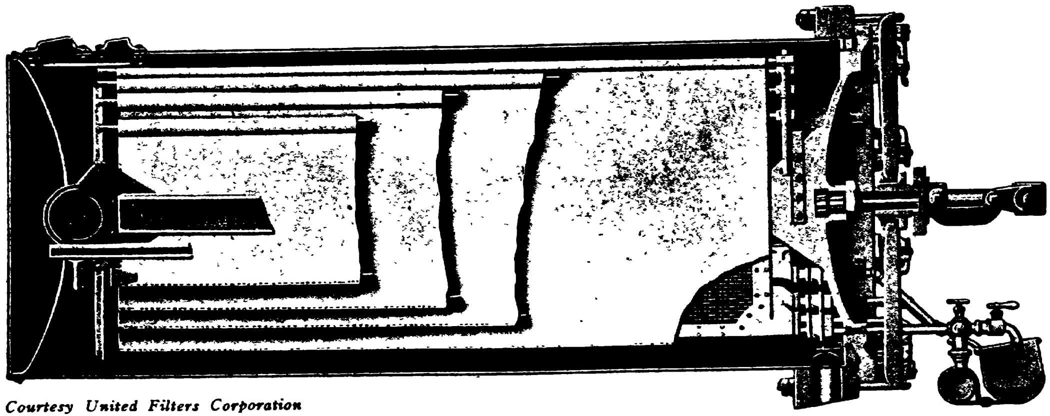
Disposition of the Leaves.—Referring to Figs. 46 and 47, a quick outline of the disposition of the leaves used in the Kelly filter is obtained. The filter leaves are spaced apart from each other at a distance dependent upon the cake to be formed: close together for thin cakes,—



Courtesy United Filters Corporation

FIG. 45.—Kelly Air Regulator.

This device insures positive pressure on the filter leaves, for after the press is filled and all the air vented from the shell, compressed air is admitted through the "Air Inlet." If the liquor level falls the "Float" is in the position shown and the valve is open, thus admitting compressed air to the filter. If the liquor level is high the float rises until the lever in its raised position closes the valve and compressed air is shut off. Consequently any stopping of the pump feeding the filter does not require the operator to switch any valves to hold the cakes in place. The regulator does this automatically.

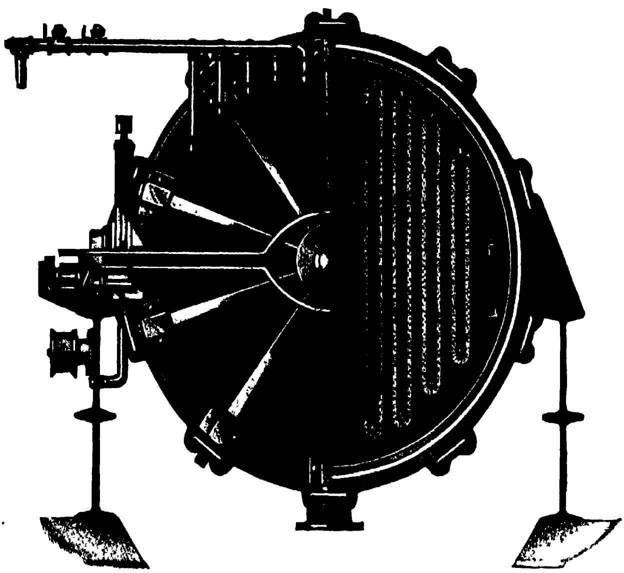


Courtesy United Filters Corporation

FIG. 46.—Longitudinal View of Kelly Filter.

The leaves are seen to be rectangular and of equal length. The ends of the filter are dished to give maximum strength. The delivery of the filtrate in this particular machine is from the bottom of the leaves through shut-off cocks. The toggle arms of the closing mechanism are seen to be in a straight line, thus insuring that the press is in locked position.

wider apart for thick ones. Disposing the leaves in planes parallel to the longitudinal axis of the cylinder naturally requires that the width of the leaves vary as the distance from the center increases. By so doing, however, the maximum filter area is obtainable and each leaf is maintained as a flat rectangle. This latter is a feature in reducing filter cloth wastage as is always the case with circular leaves. The leaves will be seen mounted on a rack carrying the rollers facilitating the movement



Courtesy United Filters Corporation

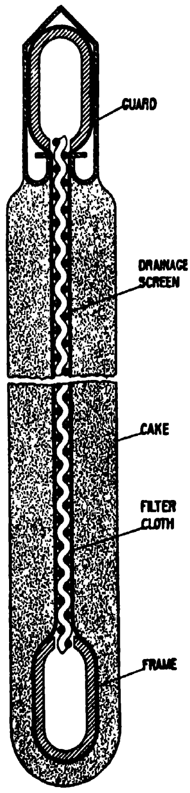
FIG. 47.—Transverse View of Kelly Filter.

The leaves are constructed of different widths to better fit the circular shell. The individual outlets from the top of the leaves carry individual outlet cocks in order to shut off leaky leaves.

in and out of the entire set of filter leaves. The customary construction of the filter leaf is shown in Fig. 48. It will be seen that though the filtrate outlet be taken at one point only, the filtrate can drain through the corrugated filter screen either at the top or bottom of the leaves. This insures adequate drainage from even long, large leaves, and makes a very strong construction for filter leaves.

Filtrate Outlet Construction.—The filtrate outlets are simple extensions through the cast-iron head of the filter. These can be made open-delivery by which each individual leaf spills into a collecting trough, a shut-off cock being provided on each outlet so that if any filter leaf fails to produce clear filtrate it can be shut off to prevent contaminating the

rest of the product. Open-delivery, while it is the simplest form of construction, is frequently less applicable than a closed-delivery construction. This varies from the above in that all the filtrate pipes are rigidly connected to a main filtrate manifold. Shut-off cocks are pro-

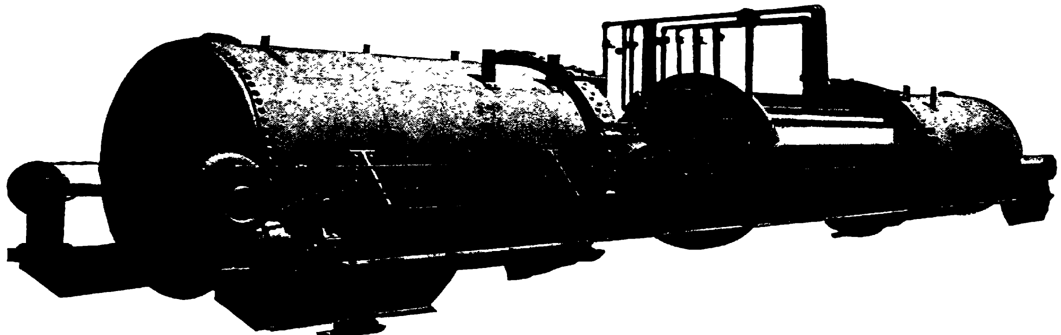


Courtesy United Filters Corporation

FIG. 48.—Kelly Filter Leaf with Cake.

The drainage frame consists of flattened pipe which surrounds the drainage screen of heavy crimped wire screen. The upper part of the leaf is covered with a metal guard which prevents cake bridging over the top of the leaf.

vided as before and either test cocks or gauge glasses are used to detect quality of filtrate flowing from each outlet. This manifold is usually supplied with a T-connection, one outlet with a valve for draining into the filtrate tank and the other with valve connected by flexible hose to a compressed air or steam line. The closed-delivery, therefore, permits



Courtesy United Filters Corporation

Fig. 49.—Kelly Filter—Large Twin Unit.

Large machines require heavy boiler plate construction, I beams, etc. The guards over the top of filter leaves are maintained in the large as well as small machines. In order to move the carriages with the leaves and to lock the filter heads, the automatic motor is used.

use of reverse current which is not convenient or feasible with the open-delivery construction. The flexible connection should always be shut off until discharging the machine, as it is there under pressure and for only a short period in the entire cycle of operation. When the filter is thus connected, no trouble is encountered with the flexible connection although, obviously, any design is better that does not use such connection.

Twin Unit Arrangement.—This is a novel arrangement of two Kelly filters whereby a saving of 20 per cent in floor space is effected and in which the locking mechanism of both filters is controlled by one air motor. It is confined to the larger sizes and makes the operation of the two filters a much simpler job for the operator, especially if the total cycle is short.

The secret of the success of this arrangement lies in the modification of the standard air locking mechanism. The one air motor, chains and sets of sprockets is used to open and close each filter. By incorporating a slotted bar as a substitute for several links in each chain and providing on each filter a coupling pin that can be slipped into one of the slots in this bar, quite similar to the principle of the Gould Coupler on railway cars, the forward or backward motion of the air motor opens or closes a filter. Only one filter can be opened and discharged at a time and each unit is generally operated alternately, although when half capacity is desired one filter only may be used. If the cakes are waste materials and may be mixed, separate materials may be handled in each machine. This flexibility is desirable and advantageous. The slotted bar used as a link in the chain is coupled by means of the coupling pin to a rigid cross bar. This cross bar is the same as used in the standard machine or to which the chains are attached in the single unit. Consequently, with this scheme of operating first the cross bar on one filter, removing its coupling pin and engaging the coupling pin of the other filter, the closing of each filter is a duplication of the locking and opening of the standard filter.

Operation.—The operation of the Kelly filter which is a typical pressure leaf machine, will be found to differ greatly from the operation of suction leaf filters. The primary difference lies in the method of handling the slurry to be filtered. In suction leaf filters this is pumped only as local conditions require from one elevation to another, or in order to provide circulation in the filter tank. But in pressure filters, the liquor must always be pumped, or be under static pressure or its equivalent, so as to provide the force necessary to do the work of filtration. The other marked difference is the requiring of control of the pressure in the filter so that it shall never equal atmospheric pressure during any part of the filtering cycle (including washing and dewatering) until the cycle is completed. This means that after filtration, when the excess unfiltered liquor is drained from the machine, compressed air must be admitted to take the place of the excess liquor, and similarly after washing. This necessitates a valve manipulation that is not necessary in suction filters, or in plate and frame practice. The complication of operating the valves is simple routine after one or two runs, so that unskilled operators have no trouble in handling Kelly filters. There is

quite a similarity in the matter of discharging Kelly filters and Moore suction leaf filters. In both cases the leaves are conveyed over a hopper or receiving tank and there discharged. In Kelly filters this requires simply the moving of the carriage supporting the filter leaves out of the shell of the machine.

In operation of the Kelly filter the first step is to lock the filter in its closed position and admit the material to be filtered. During the filling operation an air vent located at the top of the machine must be open, unless the filter is equipped with an air regulating device with blow-off connections, in which case the air escapes through the blow-off. When the filter is filled, the liquor issues from the air vent or the float in the air regulating device operates and closes the blow-off. The air vent is then shut and the pressure from the pump, montejus, or gravity feed, forces the liquid through the pores of the filter fabric to the interior of the filter leaves which is at atmospheric pressure. The amount of pressure to be employed varies with the material handled, but since the filter is designed to withstand a pressure of 75 lbs. per sq in., any pressure can be used with safety up to 60 lbs. per sq. in. Twenty-two inches of vacuum or 11 lbs. per sq. in. is the average pressure in the operation of vacuum filters. The difference therefore between 11 lbs. and 60 lbs. per sq. in. represents the cardinal difference in the two types of filters—suction and pressure.

Filtration progresses with the cakes building upon the filter cloths, in most instances in an even thickness. If the slurry contains coarse materials which tend to settle readily, it is often necessary to pipe an overflow line from the top of the filter at the end opposite to the inlet connection, or from outlet tappings evenly spaced at the top of the filter. By piping the overflow line back to the source of supply any amount of circulation can be obtained in the filter by controlling the shut-off valve on the overflow line. This circulation, which is in reality an uprising current of the liquor between the leaves, tends to distribute evenly the coarse particles throughout the mass of the cake. In most instances it is a very successful means of producing even thicknesses of cake even with otherwise granular material. As in the case of suction filters, in the Kelly and all pressure leaf filters, the leaves must be so placed apart that the cakes built up on the leaves will not touch cakes on adjoining leaves. Obviously leaf spacing is determined by experience either from small scale laboratory tests or from plant practice on the same material manufactured under the same conditions. The leaf spacing is not made for the possible cake that can be built up, but for the economical cake. Economical means in this case that thickness at which the flow has decreased to an economical minimum determined both by the actual flow produced at that time and with consideration of the time required for the subsequent operations of washing and dewatering. The spacing is considered correct when there remains a 3/8 in. clear passage for wash water, etc., after the economical cake has been produced. This is equivalent to that considered best practice in suction leaf filters and differs from that practical in the self-discharge plate and

frame filters of the Atkins-Shriver and Merrill type. In these machines a much smaller spacing is required between the deposited cakes.

Granting that the spacing has been made to comply with tests conducted on a true average of the material, there must still be left to the operator's discretion the exact economical limit for each run. This is because the materials handled in the industries are variables. This variation should, however, be confined entirely to the material itself and not be due to changes in temperature and density of the materials fed to the filter. These are controllable and should be maintained constant, one run after another. The variation that will occur, however, is in the material itself, and is due to a change in the impurities that different batches contain. There is, consequently, no guide quite as informative as the experience gained by observing the cake formation after each run. In an endeavor to assist the operators of Kelly filters, especially in the beet sugar field, a cake tester was installed on machines in several different plants. The original cake tester consisted of a simple revolvable shaft placed between two leaves at the locking end of the machine. On the inside this shaft was turned at right angles and carried a sheet metal disc so that the operator could turn the revolvable shaft and determine by the stopping point the size of the cake built up. Another scheme of cake testing was to provide a sliding rod perpendicular to the surface of one end of the leaves. On the inside this sliding rod was provided with a sheet metal disc. This disc was set away from the filter leaf ⅛ in. less than the desired cake thickness. When the cake had built up so as to touch the disc, the disc started then to move in toward the filter cloth and thus give signal to the operator by contact of electrical circuit with bell or light. These devices were soon found not infallible and, from the nature of industrial filtration, it would be hard to make them more than mere indications to help the operator. For instance, if the filter cloth at the point of application of the cake tester is not thoroughly cleaned it is not representative of the rest of the filter area and the cake at that point is less than throughout the machine. It must not be inferred that it is difficult to gauge the economical thickness of cake in Kelly filters, as one needs but to remember that the Kelly filter enjoyed a wide popularity, especially in the beet sugar industry, and its operation proved it a tremendous advance over plate and frame presses and suction leaf filters. The operation is entirely a matter of the efficiency of the man operating the machine, and it is surprising how quickly the lowest class of unskilled labor can perfect the operation of the machine if properly instructed in the initial operation.

Draining the Filter.—When the filtration cycle is completed, it is necessary to drain the filter of the excess unfiltered liquor lying about the filter leaves, whether the cake is to be washed free of the entrained solubles or whether it is to be dewatered and discharged without washing. Draining the excess from the filter is preferably done by opening a drain connection feeding into a sump or receiving tank located below the filter. Having a gravity flow to the sump requires the minimum air pressure within the filter. Excessive pressures are to be avoided. Consequently,

when draining the excess from the filter, the first operation is to close the inlet line and, if the filter is not equipped with an air regulating device, open a compressed air line feeding to the top of the filter (usually a T from the same tapping for the air vent). If the filter is equipped with the air regulating device the compressed air is admitted automatically. As we have seen, the use of compressed air is to make the cake adhere to the filter leaf, since any positive difference in pressure between the outside of the filter cake and the interior of the filter leaf of at least 3 lbs. per sq. in. will hold the cakes in place, it is advisable to make sure the air is on as quickly as possible after shutting off the inlet line. A precaution about admitting low pressure compressed air too soon is needless, for if the compressed air line is equipped with a check valve, irrespective of the pressure in the filter, the sludge cannot then fill the compressed air line. Difficulty on this score is only found when the check valve is omitted, and the inlet valve does not completely shut off. Leaky valves have no place in economical filtration, and it is a positive part of the operator's work to maintain his valves in good condition. Low pressure compressed air is used for draining the excess and it is best when maintained not over 10 lbs. per sq. in. nor under 5 lbs. per sq. in. As the excess sludge drains from the filter, the upper part of the cakes are subjected to the partial drying effect of the compressed air. In consequence, the draining should be accomplished as quickly as possible and oversize pipe lines are the practical means of making the transfer quickly. The diameter of the drain line should average at least 50 per cent greater than the diameter of the inlet line. The latter is determined by the size of the filter, both in respect to the filter capacity and the time required to fill the filter at the start of the operation. Therefore, with a drain line of 50 per cent greater diameter, and with an unfiltered liquor excess that should average less than half the liquor required to fill the filter at the start of operation, the draining time should not be over 1½ to 2 minutes. Promptly upon air issuing from the draining valve, the drain should be closed and wash water admitted. The wash water is generally at a pressure in excess of that maintained at the close of the filtering cycle and the compressed air should be vented fast enough so that the pressure is held between 5 and 10 lbs. per sq. in. until the filter is filled with wash water.

The need of draining out the excess unfiltered liquor before admitting the wash water has been the subject of much discussion. The control and operation of the filter would be far simpler if it were possible to eliminate the draining and re-filling operations. Irrespective of this advantage, it is the economical means of operating Kelly filters. With the excess unfiltered liquor in the filter, the wash water becomes enriched, so that instead of washing with water or weak liquor, as the case may be, in reality it is washing with diluted strong liquor. This is not good practice, but worse yet, is the fact that the enriching effect is not constant, being very much more prolonged at the sides of the small leaves than in between the larger leaves at the center. If it were that this enrichment added to the time necessary for washing or in the amount of weak filtrate

produced, this might be enough to condemn its practice, but it is impractical to wash the cakes completely free of soluble, since there is no adequate test by which the operator can judge when the cakes are washed. In some instances, especially where there has been sedimentation in the bottom of the shell, before admitting the wash water, the bottom of the shell is flushed out, the idea being to remove this material with the strong liquor in it, to prevent enrichment of the wash water by sediment, similar to that discussed above.

If the excess unfiltered liquor has been drained quickly and positive pressure maintained in the machine throughout this operation; if the wash water has been admitted and the air vented so as to maintain a positive but relatively low pressure, then the filter cakes will be in approximately the same condition as they were at the end of the filtering cycle. Displacement washing will result in the high washing efficiency of which this filter is capable. It is, of course, assumed that the cakes on the leaves have not touched each other at any point, so that each of them is completely submerged with free passage for wash water.

Washing.—There is undoubtedly no greater factor contributing to the fall in popularity of the Kelly filters than the failure of operators to obtain true displacement wash in actual operation. This is not hard to understand, for, let the compressed air be turned off, or in any other way the pressure be dropped during draining, and some of the cake is liable to be pulled off the leaves. This manifestly destroys the very foundation of displacement washing, for now there are paths where the water can penetrate faster than at other points. Or, let the transfer and re-filling with wash water be prolonged, the top of the cake will be found to be partially dried and possibly cracked. This, too, defeats displacement washing.

It was therefore hailed with considerable enthusiasm when the suggestion was first made that there could be a fool-proof scheme of washing by displacement any cake built in Kelly or other leaf filters. The scheme is simplicity itself, for it substitutes a muddy wash water for clear wash water. The mud is usually washed cake from a previous run, and while it requires a separate tank equipped with agitators, it is surely a trivial item compared with better washing results. It is safe to say that many a faulty Kelly filter installation would still be in good repute had this scheme been applied. The mud of suspension in wash water fills up the cracks, open spaces, and other points of low resistance, until the resistance of the surface throughout the filter again becomes uniform. From that point on, washing is really a continuation of filtration. It is thus seen that if anything short of wilful misoperation occurs, this scheme will still guarantee complete washing and a close approximation of displacement wash.

The amount of mud to put into the wash water is very largely a consideration of the material being handled. With a free filtering solid it is even possible to use inert clays, or other slow filtering materials, to better advantage than unwashed cake of previous runs. In washing

slow filtering materials, the solids present can be very much reduced from those necessary in washing the cakes from free filtering materials.

It is always difficult to lay down general laws for the operation of any industrial filter, and, at best, such laws are only applicable to a majority of installations. Consequently, when it is stated that the wash water should be fed in with an initial pressure slightly in excess of the limiting pressure during filtration, it is an adage for the majority of applications, but bound to have a large number of exceptions. However, if the wash water is muddied this law will be found to be largely applicable. The reasons favoring this higher pressure are not hard to find. It is assumed, of course, that the filtering operation was confined to a pressure within the limits of the critical pressure for the material in hand, and that the pressure during washing does not exceed critical pressure. Then the higher pressure tends to compress the cake, which means decreasing the voids and thereby lessening the requirements of the displacing wash water and also insures maximum rate of flow during the washing cycle. The latter is not generally a big factor, as the strong liquor to be washed out of the cake has, in most instances, a specific gravity well in excess of the wash water so that its viscosity is also greater than the wash water. However, if the wash water is a clear liquid, this increased rate of flow jeopardizes complete washing of the cake, for it often means washing out parts of the leaves in advance of the remainder, whereas if the water carries solids of suspension, the more water filtered, the more solids deposited, and the more even washing obtained. This idea of using a higher pressure during the washing cycle is a reversion back to the laws governing the operation of plate and frame presses where the same idea was used. In many installations the higher pressure did not help, and so confidence was lost in the old law, but the number of instances where it has not been applicable has been grossly exaggerated.

There seems to be a rather unique repetition in the different steps of the cycle of filter operation preparatory to the next step. For instance, in filtration the uniformity of cake building plays an important part in the washing operation and now we find that the compressing effect on the cake during washing aids in the drying operation.

Drying.—The drying operation follows the washing, the initial step in which is to remove the excess unfiltered wash water. This is drained back to the wash water supply tank, which is preferably located below the filter so as to require no head for its removal. Pressure must be maintained in the shell, as in the case of washing, or otherwise some cake will slough off the leaves. Therefore, the pressure during the withdrawal must be positive, but it is best when maintained between 5 and 10 lbs. per sq. in. As soon as the wash water is out, which is indicated by a chattering of the drain valve, the drying commences and the drain valve is closed.

Drying these cakes is removing the excess moisture from the voids of the cake. In effect, it is the filtration of compressed air through the cakes. The one big drawback is in the early cracking of the cake, there-

fore every means that will delay this cracking is an advantage. This is the prime reason for maintaining a pressure not too high at the start of the drying operation. The limit for the initial pressure is one of the most variable factors in connection with industrial filtration. It differs with the material, even though the material itself is common to that produced in the manufacture of another product and is dependent entirely upon the particle size and density of the cake built up. The pressure can be higher with cakes from free-filtering liquors than it can be from those with finer particles of suspension.

At best, however, the drying operation is the weak spot of leaf filters. The Kelly filter, by means of bottom outlets, will often deliver dryer cakes than can be obtained in some of the other types of leaf filters, but excessively long leaves do not give much advantage on this point.

To prolong the drying cycle after the pressure drops to one half the limiting filtering pressure is generally a wasteful procedure. It takes horsepower to compress air, and the volumes required when the cakes have cracked open will always be found to be excessive.

Discharging.—As soon as the compressed air is released, the machine is ready to be discharged. The first step is to unlock and open the filter. If the delivery from the filtrate manifold has been into open troughs, the valve must be closed or a flexible hose connection must be attached so as to feed reversed compressed air into the interior of the filter leaves, so that the cakes may be discharged without hand labor.

The carriage containing the leaves should move out of the shell with as smooth a motion as possible. A jerky motion will dislodge some of the cake and tend to lessen the efficiency of the reverse current discharging. The compressed air in the interior of the leaves in reality filters out through the filter cloth and impinges the cake. Naturally then, if the cake has been dislodged, the air penetrates through at this point with less resistance.

The reverse air should have for its function the lifting of the cake away from the surface of the filter cloth. It is not an air blast and the pressure of the reverse air should be maintained under a maximum of 10 lbs. per sq. in. so as not to harm the cloth. If the filter cloth is unsupported, save at the edge of the leaves, there is danger that the reverse current will balloon the cloth and distend it so that the air, if it disengages the cake, must lift it almost vertically. This condition does not exist in practice for with the leaves on close centers, as most filters are designed, this means pushing adjacent cakes together. Of itself, this is possibly not a disadvantage, but in falling, this cake often jams between the leaves and holds up further discharge. There are, therefore, very few instances where ballooning of the cloth is not poor practice. There are many schemes for reducing this and they are dependent largely upon the type of drainage member used, but one of the most popular methods is to secure the cloth every six inches with hollow eyelet rivets.

Compressed air typifies the reverse current agents used in discharging Kelly filters, but low pressure steam is often used and is in some

instances a better agent than compressed air. Steam, of course, should never be used save in the handling of hot liquors.

Great hopes were once held that an automatic sluicing arrangement would be perfected for Kelly filters. The elements of good discharge by this method would seem to be in the fact that the sluicing streams would need to throw but a short distance and that the sluicing nozzles could be fixed in position and the leaves rolled in and out against them. The sluicing discharge, coupled with reverse steam, made an excellent means of cleaning the Kelly filters tried out on raw cane sugar. However, sluicing discharge is confined to those materials which build up cakes of small thicknesses, and, for these liquors, closer leaf-spacing is obtainable in Sweetland filters than in the Kelly, and therefore greater filter area per square foot of floor space is secured.

An interesting method of discharge, although not presented as an acceptable method of discharging Kelly filters, is the high pressure air blast systems. In this the operator plays the nozzle of an air hose, pressure usually being around 75 lbs. per sq. in., at the top of the leaves. The cake discharged is then blown across until it hits the other leaf, rebounding back and hitting the original leaf and repeating until it blows out at the bottom. After the air leaves the hose, it becomes no longer compressed air, but a veritable air blast, and will clean cloths that have been gummed up with organic waxes, so thorough is the cleaning action. Filter cloth is, of course, never constructed to withstand such treatment and its life is short. The factor of the baffled current cleaning the leaves is beautifully demonstrated here and has led to the application of this principle in the sluicing discharge of Sweetland filters.

Any method of discharge from Kelly filters is primarily a sloppy operation in that the cake falls and is never completely firm and is liable to splash so that some of it flies all over. It is, therefore, good practice to house in the discharge hopper by side plates (as shown in Fig. 44) which will reduce this condition so that it becomes negligible as a drawback. In sluicing discharge, these side plates on the hopper should be supplemented with a sheet covering to prevent splashing in all directions.

Discharge from the leaves is often incomplete, even if the surface of the cloths be quite clean. The cloths will be found clogged beneath the surface with scale formation, or entrapped solids. These impediments must be removed or the capacity of the filter drops. But extraordinary methods must be applied—the scale material must be dissolved out of the cloth and generally the dissolving action is quickest when using weak hydrochloric acid. This weak acid is corrosive, not only to the filter cloth, but even more so to the materials of construction and its use is hazardous at best and requires careful watching and control, or more harm than good results. The concentration of the acid, the temperature of the solution, and the time of contact with the scaled cloth are all dependent upon the amount of scale present and whether it is a carbonate or sulphate. Experience is the only judge for the local plant. In some installations the weak acid is pumped into the filter and the cloths stand immersed in it. In others, reversed compressed air is forced through the cloths

to hasten the dissolving action. Steam has also been used as a substitute for the compressed air. One plant obtained excellent results by first thoroughly cleaning the filter leaves and filter proper and then pumping the acid through the cloths in a reverse direction, re-pumping the overflow from the top of the machine as a circulation. This is undoubtedly the best method provided the acid stays clean so that a deposit does not form on the inner side of the filter cloth. When the impediment is a solid of suspension, especially from organic liquors, filling the filter with hot water and to reverse steam through the filter cloths gives the desired result.

The cycle of operations on the Kelly filter is complete with the closing of the machine. This has been outlined before, but so many operators are negligent of proper care of the gasket that the caution is advisable that the gasket and the impinging metal surface be kept clean, when leaks will be avoided and the gasket will hold out for a life of 6 to 18 months.

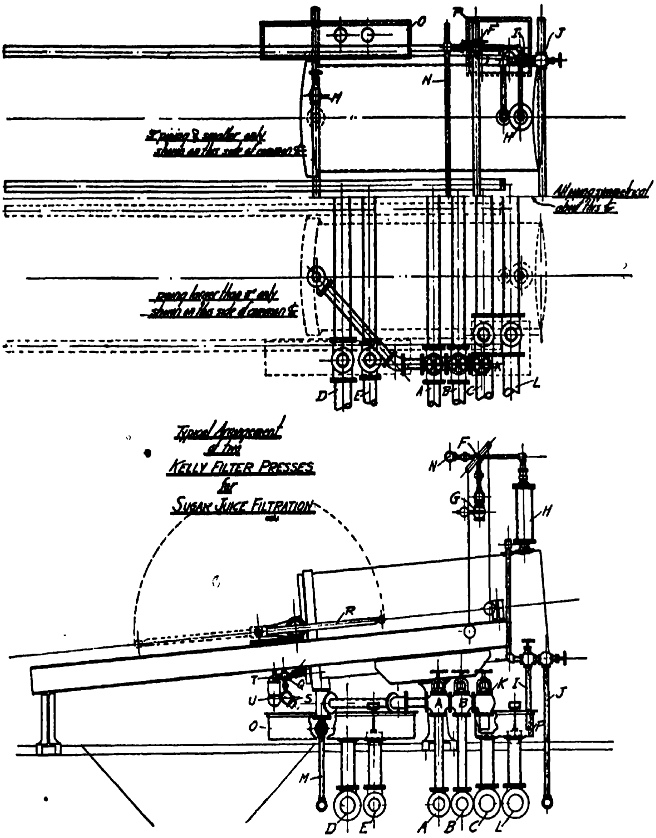
Layout.—The location of the Kelly filter in the plant is often attempted with the idea of using available space and with insufficient regard for its location with respect to feed tanks, pumps, filtrate delivery and accessibility for control of valves. This has led to more than one installation turning out to be but a partial success instead of a complete success. *Convenience of operation* is not a fad, lessening the work of the operator, but *a necessity* enabling the operator *to obtain best results.* In the Kelly filter there is considerable piping and transferring of the liquors and the easier the valve control, the shorter the time not used for actual filtration, and the more positively can pressure be maintained at all times. No layout can be made standard for every installation, but the correct layout should be made the goal, and present installations not conforming to such correct layout, as shown in Fig. 50, can well be changed. Note that the filter is best set into the floor, with center line at the floor level.

Advantages.—Of all pressure leaf filters, the Kelly is the simplest in design and cheapest in cost of manufacture. Using the cylindrical shape with one end closed makes the casing on this filter a straight boiler shop job. The movable head, made of cast iron; with the cast iron ring for gasket service, comprises the only heavy casting work required.

The Kelly filter early proved that for many materials handled in industrial chemical plants, the capacity per unit filter surface is greater than that obtainable in suction leaf filter and plate and frame filter presses. Compared with the Sweetland and Vallez filters, the capacity during filtration is equal, but the output per day, including time out for transferring liquors, etc., will generally be found to be under other continuous filters.

Making the Kelly filter leaves rectangular preserves a feature found in the square type plate and frame presses and in suction leaf filters, of requiring no circular cutting or loss of filter cloth. Different widths of cloth are required, of course, if the narrow side leaves, the intermediate and center leaves, be covered without cutting wide cloths to waste.

The actual floor space required by the Kelly filter is not excessive



Courtesy United Filters Corporation

FIG. 50.—Kelly Filter Layout.

Whether for inclined or horizontal types the use of angle valves to form a manifold is the convenient arrangement for controlling the operation of the filter. Cone plugs are the simplest means of switching from cloudy to clear liquor in the filtrate launder. The outstanding feature of the Kelly Filter Layout is the accessibility of all valves within easy reach of the operator.

even in single units, but the space is long and narrow. With the twin unit, however, the floor space required is a minimum for pressure leaf filters maintaining accessibility of filter leaves. The headroom likewise is small in Kelly filters, since there is no need of hoisting any part of the machine above its stationary position, nor are there any movable counterweights that travel above it.

The displacement washing obtainable in suction leaf filters is maintained in Kelly filters, and if wash water is muddied, washing the cakes is positive and efficient.

The Kelly filter has but one main gasket joint, circular in shape, and by far the simplest gasket found in any pressure filter, including plate and frame presses. It is simple to maintain this joint leak-proof at all times.

The stationary cylinder with its unobstructed surface is admirably adapted for heat insulation by asbestos or magnesia covering.

Drawbacks.—There has been a mistaken idea that the filter area in Kelly filters is most accessible. The filter leaves on the sides are most positively so, but the leaves at the center can be observed only from a position at one end, or, in the case of twin units, from a point above the filter leaves. It is self-evident that the cloth, viewed from a distance, cannot be properly inspected. Accessibility for observing the condition of the filter surface is not vital, but is valuable if the operator desires to get the best possible work out of this type of machine.

Dividing the cylinder with square leaves placed parallel to the axis necessitates a large part of the space being left unutilized. This excess space becomes filled with excess liquor and adds to the time required for transference of residual liquors, and so hinders the operator's work. This is emphasized when having to pre-coat the cloths before starting filtration.

In machines of large diameter, individual filter leaves become heavy and cumbersome and require additional labor for their removal and recovering. Having different sized leaves, any one leaf is not interchangeable with every other, so if spares are kept on hand, one of each size is required.

The filter leaves are supported at the two ends and, as the length of the filter is best proportioned at twice the diameter of the shell, the span between supports is large. Consequently, if the machine is overcharged with cake, the damage done by warping the leaves is heavy and requires that the warped leaves be removed and straightened outside of the machine.

Flexible connections are always makeshifts in plant practice, as they are necessarily weaker and often become troublesome when the attaching threads or flanges become worn. The Kelly filter, requiring a flexible connection on filtrate discharge, is therefore weak in this detail.

As in the case of suction leaf filters, drying the cakes by filtering air through them is not a satisfactory means of dewatering filter cakes.

The I-beams or channel irons on which the carriage, carrying the leaves, rolls, become shelves on which the solids of suspension deposit and soon eliminate rolling contact of the rollers so that the carriage slides through the mud on these supports.

This movement of the filter leaf carriage on the side supports condemns lead lining or other protective coatings in this filter, as lead and other coatings will not stand the abrasive effect of the loaded carriage on the supports.

The Kelly, as well as the suction leaf and other pressure leaf filters, is intermittent in operation and, as such, its efficiency is dependent upon the skill of the operator. The work required of the operator in handling this type of machine is not great, but careless operation can result in both low efficiency and big losses.

Applications.—The Kelly, being the first pressure leaf filter on the market, was introduced into a large number of industries. Its advent was heralded as "a filter press that embodies all the advantages of leaf filters, and shows economies of operation over plate and frame presses that can net an annual return of 100 per cent on cost of installation." The Kelly, therefore, was applied as a substitute for existing filter presses. These replacements took place in oil refining; in starch plants; in causticizing; aluminum hydrate; intermediate dyes, and other general chemical manufacturing plants. The one industry where more plate and frame presses went out and Kelly filters went in, is the beet sugar industry. Here the Kelly was used very successfully, for first and second carbonation juices; filtering calcium carbonate from the sugar liquor, and washing the sugar from the cake.

In general, the Kelly is applicable to any filtration liquor, hot or cold, small or heavy concentration of solids in feed where the solids are desired free of soluble.

These filters are not adapted to acid liquors, nor for those materials in which hard, dry cakes are required, and they have not been developed for sluicing discharge.

Summary.—The Kelly filter, as the first pressure leaf filter, has earned an enviable reputation. The economies effected by its installation, replacing plate and frame filter presses and making applicable leaf filters to those materials not handled with suction leaf filters, represents a large amount of capital.

The drawbacks to the Kelly filter are in most instances overcome in the Sweetland filter, the design of which has been developed through a decade, and the Sweetland machine will therefore be taken up next.

Chapter V.

Section II—The Sweetland Filter.

The Sweetland Filter, earlier known as the "Clam Shell" filter, has for its basic principle, leaf filtration under pressure, identical with that of the Kelly, from which it differs only in the mechanics of design. It is, perhaps, the leading filter working on this principle, as evidenced by the great numbers found in the industries today.

History and Development.—This filter has had a considerable development from Ernest J. Sweetland's first machine. Sweetland was a mill superintendent for a gold mining company when he first applied himself to filtration. There were installed in his plant a battery of Butters' filters which began to fall off in capacity due to a change in the character of the ore being worked. Trying every known "trick of the trade," but still failing to get sufficient output, he decided that the vacuum pressure was not great enough for his slimes. Greater pressure meant using plate presses, until he thought of the scheme of inserting filter leaves in the frames of a conventional plate press and eliminating the plates. This he attempted to do, but found that there were considerable modifications necessary and thereupon he worked out a new design and built his first filter.

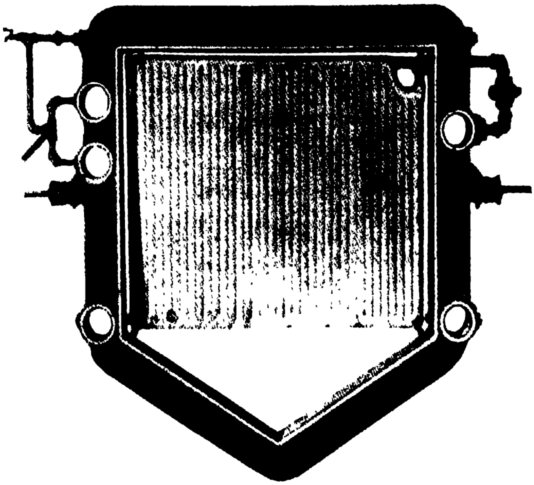
Design of First Sweetland Filter.—The starting point in his design was to provide gaskets between abutting frames, since the removal of the plates and conventional filter cloth left him without a gasket. This he worked out by machining a groove in one side of each frame and inserting in it a square rubber gasket with 1/8 in. protruding. The groove in the frames was usually 3/8 in. wide by 1/4 in. deep, so that a 3/8 in. square gasket fitted and left the 1/8 in. protrusion desired. Joining the ends of this gasket was at first a nice splicing job, but later butt-joints proved equally effective, provided a slight excess of gasket was forced into the groove so that there was positive pressure against the butting joints.

The second modification in the design was to make the frames thick enough to allow outlet pipes for the leaves to be inserted through them. At first thought this would seem to indicate that less filter area could be provided for a given length of filter, since fewer thick frames can be placed in the filter. It is true that the filter leaves are thus placed further apart,—and must be, if the principle of leaf filtration be maintained. One of the primary requisites is that the fully formed cakes on adjacent leaves shall not touch each other, and here is one of the reasons for this extra spacing. It must be remembered that the plates were eliminated and this

left room to allow the same number of leaves as filter plates in the conventional filter.

The method of attaching the leaves consisted of threading a small pipe nipple into a tapped opening in the frame leading to a filtrate outlet. A similar short nipple extending from the filter leaf was connected with the nipple in the frame with a conventional pipe union. Clips at the other three corners aligned and supported the weight of the leaf.

A further modification was necessary in order to provide space for the discharged cake. This consisted simply in making the lower part of



Courtesy United Filters Corporation

FIG. 51.—Earliest Type of Sweetland Filter.

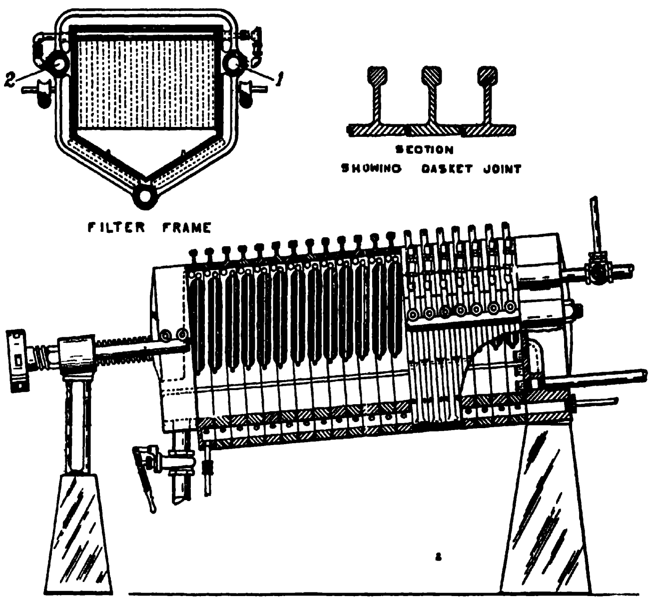
Each frame carries a filter leaf suspended by a nipple and union from a cored filtrate outlet and aligned at the lower corners by clips. The bottom of the frame is V shape to accommodate the cake when discharged from the leaf to be sluiced from the filter.

the frame of a V-like trough section. As the filter leaf was not allowed to extend to this part of the frame, an open trough was formed the full length of the press. Sweetland was quick to realize that if the cake fell into this trough, he would have trouble in removing it unless there were a decided pitch to the trough. Here lies the secret of the inclined position of his early filters. This is shown in Fig. 52.

At first, one is bewildered at the perpendicular position of the leaves as compared with the inclined position of the frames. On second thought, however, it is evident that the frames must be perpendicular to the side arms and to the locking screw, or else the closing pressure would not clamp the frames evenly together. On the other hand, the leaves must

be vertical or else the cakes could not be discharged by reversed current from the upper side of the leaves.

Sweetland's genius for mechanics stood out in this first of his filters. Note the T-rail cross section of the frame,—the same principle underlying the design of I-beams—was incorporated in the design of these frames. This had an economic value of no small importance. We must remember



Courtesy United Filters Corporation

FIG. 52.—Earliest Type of Sweetland Filter.

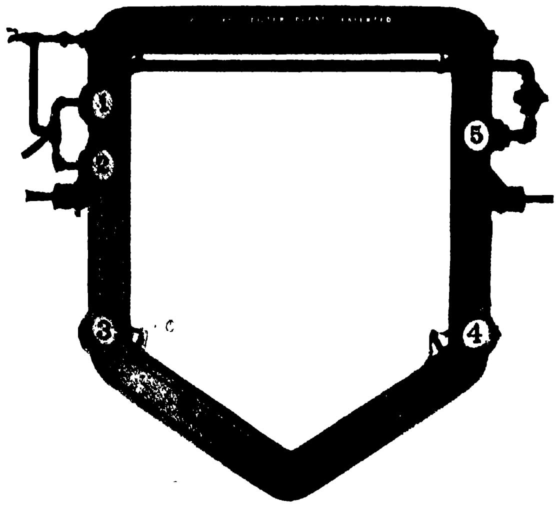
The filter is an assembly of separate frames, each carrying its own leaf, on inclined side arms. The leaves hang vertically with plenty of clear space below to insure thorough discharge of cake. Each frame is constructed on the T rail principle to obtain maximum strength and to allow high internal pressures—the dominating feature of the first Sweetland Filter.

that he had in mind increasing production by using high pressures. To withstand internal pressure, such as this design of frame can successfully resist, ordinary frames would have to be made of semi-steel or else have metal extremely thick, and weighing many times more than this.

The idea of inserting square rubber packing as a gasket met with considerable skepticism from many quarters. It was thought that the bearing area was too small and would permit leakage past this gasket. In point of fact, a pure gum rubber strip was used, which has sufficient resiliency to make a tight joint with a relatively low closing pressure. Exposing only

⅛ in. of the gasket beyond the surface of the frame insured very small pressure against the gasket, even when the filtering pressure rose to 150 lbs. per sq. in.

Five eyes were provided in the frame (shown in Fig. 53) which made continuous passageways through the filter when a press was assembled. That marked 1 provided for the collection of cloudy filtrate, in case any one leaf became fouled and leaked. Eye 2 was used for clear filtrate. The test cock shown at the extreme upper left corner served to detect leaky leaves. A 3-way valve located on the branch piping to the eyes 1 and



Courtesy United Filters Corporation

FIG. 53.—Earliest Sweetland Filter Frame.

Several conduits formed by adjacent eyes in each frame are, No. 1, cloudy filtrate; No. 2, clear filtrate; No. 3 and No. 4, water jets to scour cake from corners; and No. 5, sluicing water to discharge cakes from leaves.

2 served as quick switching valve to direct the filtrate flowing into eye 2, into eye 1. Obviously, conduit 2 provides means for introducing a reverse current (of steam water, or compressed air) to discharge the cake from the leaves. Eyes 3 and 4 were provided to project jets of water to clean out any cake that might hang up in the corners of the trough. Eye 5 was the spray water conduit by which water was fed into the spray pipes located between each pair of leaves. The water from these pipes functioned in assisting the discharge of the cake and washing down the filter cloths. Note the shut-off cock provided on each pipe. By shutting off all save one of these pipes, the entire pressure of the pump could be centered on the one open pipe, thus increasing the force of the stream playing upon the cake or cloth.

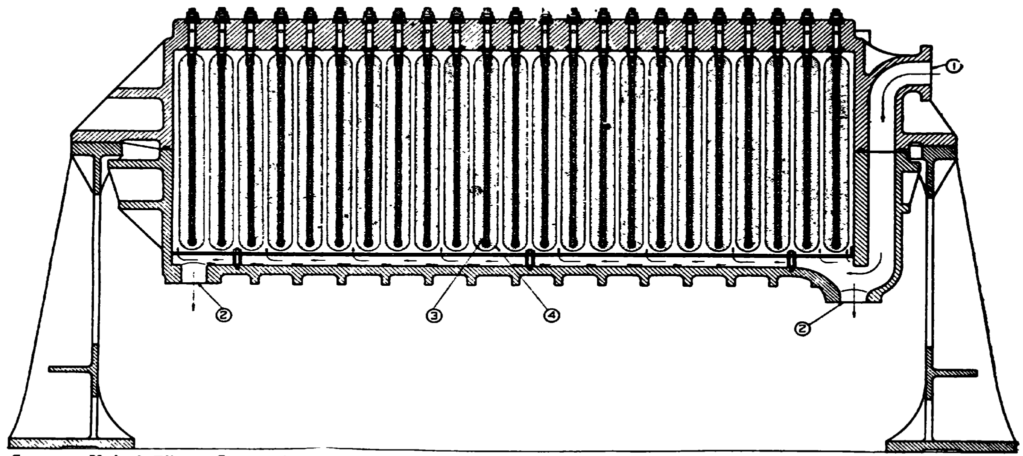
Operation of Early Filter.—The operation of this first Sweetland filter was a cross between that of the plate and frame press and the operation of suction leaf filters. In filling the machine with liquor, it parallels plate and frame operation, but filtration in the Sweetland was stopped before the cakes on adjacent leaves touched each other,—which is like suction leaf work. After filtration was completed, the excess unfiltered material was drained from the filter exactly as in the operation of the Kelly filter. Re-filling with wash water and washing the soluble from the cakes was again a point of likeness. Discharging was a point of difference, for the leaves were stationary and could not be drawn out so as to discharge the cake over a hopper, but the cake, dropped down into the open space at the bottom of the filter, could be sluiced out, and the filter was operated in this manner exclusively. The difficulty of obtaining adequate discharge and the confining of the filter to sluicing methods, was its paramount weakness, and as a means of correcting this shortcoming, Sweetland designed and developed his more familiar filter,—the "Clam Shell."

Design of the Clam Shell Filter.—The mechanics of this filter have been, in a sense, a series of developments originating with the first hand-tightened unit. In this machine, each swing-bolt, front and back, had to be tightened with a socket wrench, and in addition to the labor involved, one had to be sure that the tension on the swing bolts was approximately equal or else the gasket would be squeezed too much at one point and leak at another.

What characterizes the clam shell filter is its cylindrical shell, split into two halves longitudinally. The upper half is stationary, and the lower half is hinged to the upper so as to swing at least 90 degrees. Dividing the shell longitudinally necessitates a joint that is practically impossible to obtain with boiler plate construction so that this machine must be cast. In consequence the ends of the cylinder are heavily ribbed to withstand internal pressure. The greater part of the shell is a true cylinder, but a distributing, or drainage channel is provided in the lower half and a cavity is located in the upper half into which a sluicing pipe, or overflow pipe, may be located. The filter leaves are all located in the upper half of the machine and are inserted individually in openings which have been drilled through a boss located at the zenith of the machine. By drilling these filtrate outlet openings of the machine, any desired spacing of the filter leaves can be obtained, and each filter leaf be equi-distant from the adjacent leaf throughout the entire machine.

Genius of design is disclosed by the arrangement whereby the liquor is fed to the clam shell filter. Note that the lower half is movable and carries the distributing channel and yet there are no flexible connections on this machine. The feed enters the upper half of the stationary member and a cord passageway connects at the joint of the two halves with a corresponding cored opening which leads to the distributing channel.

The upper half is rigidly bolted to the filter supports, which are preferably long enough so that the joint of the shell shall be eye-high from floor or operating platform. To save these supports from becoming



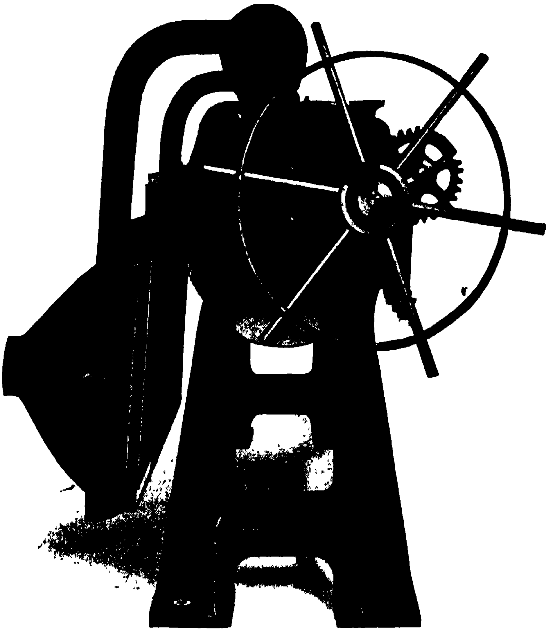
Courtesy *United Filters Corporation*

FIG. 54.—Modern Sweetland Filter (Clam Shell Design, Longitudinal Section).

The sludge inlet (No. 1) is on the stationary half but communicates through the cored passage to drainage channel extending along bottom half. A distributing plate, over the drainage channel, has openings between adjacent leaves so that liquor and wash water are admitted evenly throughout the machine. Drainage openings (No. 2) for withdrawing excess liquor or wash water are located at both ends of the machine, the one at the inlet end being located at the base of a U-shaped well to insure complete withdrawal of the liquor. The leaves (No. 3) are vertical and equidistant, and the cakes (No. 4) are built up without any cake touching an adjacent one, thus insuring free passage for wash water.

unduly heavy, they are often of a length less than required for the right position of the joint and are then mounted on concrete bases, raising the filter to the desirable height.

The lower body is counterweighted to facilitate easy movement of this half. The curved counterweight arms are necessary in order that the half be balanced by the weights in any position, as the weights must



Courtesy United Filters Corporation

FIG. 55.—Sweetland Filter—Open.

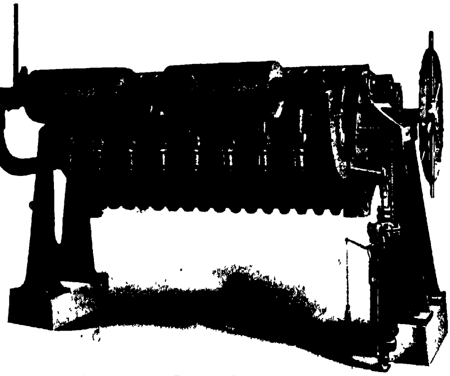
The lower half is movable and counterweighted to balance in any position. In full open position all the cake falls clear of the shell into a hopper or conveyor located below. The simple turning of the pilot wheel, without any extension handles, turns a gear keyed to the shaft on which all the swing bolts are hung, and enables the operator to easily lock or unlock the filter.

be so located that their center of gravity is on the extension of a line drawn from the center of gravity of the lower half through the center of the back hinge.

The joint between the two halves is made by the compression of a pure gum strip (or similar material) gasket carried in an accurately machined gasket groove. No gasket is carried on the lower half, but the joint forming surface of it is again accurately machined. Note that the surface of the joint on the lower half is not grooved, but identical

with the principle of the joint in the early Sweetland filter. These machines have been built 12 feet long by 4 feet diameter, positively leak proof at all times. This would at first seem remarkable, but the design contemplates a squeezing of the gasket along the rear side in advance of any compression of the gasket in front. Consequently, if the front is tightened up to be leak proof, the back and sides are bound to be water tight.

With the smaller sizes counterbalancing, the lower half is sufficient to enable the machine to be opened and shut in a fraction of a minute. But with the larger sizes, especially if any of the cake falls into the



Courtesy United Filters Corporation

Fig. 56.—Sweetland Filter—Closed—Back View.

The counterweights are carried on an extra heavy angle iron attached to curved arms so that the line through the center of gravity of the filter and the hinges passes through the center of gravity of the counterweights. The rear hinges consist of small shafts carried in individual hinge bolts, each of which is adjustable. A hydraulic or pneumatic cylinder supported from the floor and connected to one of the counterweight arms facilitates the movement of the lower half.

lower half when opening for discharging, a pneumatic or hydraulic cylinder it attached to one of the counterweight arms. This cylinder is equipped with a 4-way valve so that the pressure can be applied on its piston to move it up or down and the exhaust line is throttled so that the movement is never excessively fast. This cylinder makes it possible to swing a lower half weighing 8,000 lbs. by the press of a finger.

To align the leaves in perpendicular position and so that each leaf will be parallel to each other, the filtrate openings are counterbored to receive a washer which rests around the outlet pipe at the top of the leaf. Additional aligners are fastened to the sides of the upper half, inside, so that the leaves are held in position by 3 points: the counterbore on top and the two side aligning lugs. These aligning lugs appear as No. 7 in the cross sectional view of the filters shown in Fig. 57.

When the boss is drilled to receive the outlet nipples, it is drilled and

tapped on the front side at right angles to the center line of each of the vertical drillings in order to provide outlet connections to the filtrate manifold. From each of these drillings are assembled the outlet fittings which

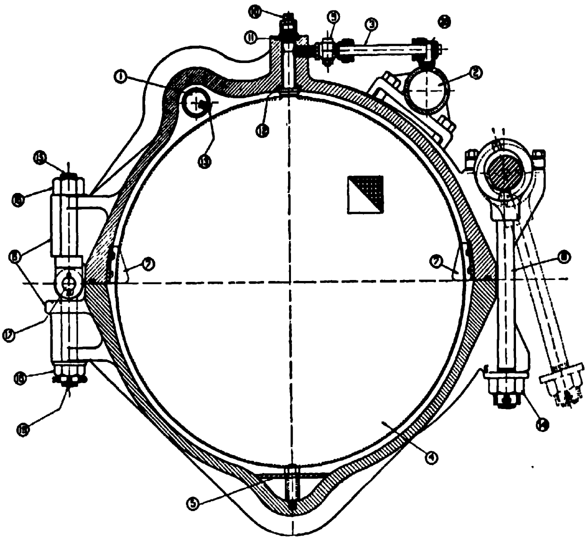


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FIG. 57.—Sweetland Filter—Transverse Cross Section.

List of Parts:

1—Internal manifold
2—Filtrate manifold
3—Sight glass
4—Filter leaf
5—Distributing plate
6—Hinge
7—Side leaf spacers
8—Swing bolt
9—Filtrate shut-off cock
10—Cap nut
11—Lead washer
12—Rubber washer
13—Nozzle
14—Swing bolt castle nut
15—Yoke hinge bolt
16—Yoke hinge bolt castle nut
17—Hinge pin
18—Plain hinge bolt castle nut
19—Plain hinge bolt
20—T outlet fitting

The circular filter leaves closely fit the curvature of the shell. Each leaf is supported by the cap nut (No. 10) from above and aligned by the leaf spacers (No. 7). The filtrate drains from the leaves into the individual outlet connections, Nos. 9, 3, 20 and 2, respectively. Each leaf is thus replaceable without disconnecting any of the outlet connections. The large swing bolts hang on the common shaft and when loosened are pushed out of line by the engagement of pins on the shaft with lugs on the bolts.

consist of a shut-off cock, sight gauge glass and pipe connection into the filtrate manifold. These are shown in Fig. 57 as No. 9, No. 3, and No. 2 respectively. This scheme of filtrate delivery is very clever, and

requires simply that the outlet pipe of the filter leaf shall be drilled at a point registering with the center line of the side drilling of the boss, so that the liquid from each leaf flows into these outlet fittings.

Each leaf is held in place by an exterior cap nut. The filtrate nipple on the leaves is proportioned so that a full thread extends above the boss, when the leaf is inserted in the filter. On top of the metal washer used to align the leaf is placed a rubber washer and under the cap nut is placed a fibre or lead washer, so that when the cap nut is screwed up tight the rubber gasket is compressed and the cap nut bears solidly on the fibre washer. By this, a simple and most effective means of preventing leaks is obtained.

The hinge on the Sweetland filter has undergone considerable development and that now used is not only the best but the simplest. Lugs are cast on the back of both upper and lower halves and drillings are made through each boss on the upper half to receive a special forked bolt. Between the forks is placed the upper end of a special hinge bolt fitted into the drillings of the lower bosses. Through the forks and through the hinge end of the bolt extend small lengths of shafting. By adjusting the castle nuts on the bolts, the lower half can be raised or lowered in relation to the upper half and the amount of compression on the gasket at the rear regulated. As the gasket wears down, sometimes every week and sometimes twice a year, the compression has to be increased and this scheme of adjusting the hinges is positive and takes care of any spring in the cast-iron over a twelve foot length. Of course, there is a possible weakness in this construction should the operator excessively tighten one bolt more than the others for then the pressure, when closing the filter, might be sufficient to crack the lug or strain the shell itself. This is a possibility not yet experienced in practice. Fig. 57 shows the hinge construction.

Locking the two halves pressure tight is a simple process—turning an eccentric shaft through 180°—but the mechanics involved are as original and effective as have been developed in connection with filtering apparatus.

The locking mechanism supplanted the original hand tightened swing bolts used on the first models. It represented a big advance, as it not only cuts down the time for opening and closing a filter, but makes the work easier and free from the danger of unequally tightening each bolt. The locking mechanism represented to the Sweetland Filter what the self-starter means to the automobile today.

In getting a good perspective of the locking mechanism, the specifications must be realized. The hydraulic cylinder almost closes the lower half, so that the front gasket surface nearly touches the gasket in the upper half. It cannot close the shell entirely, as the compression of the back gasket must be in advance of the front gasket and it would be foolish to put on a hydraulic cylinder of sufficient power to fully compress it. The gap in front never should be greater than ⅜ in. The locking mechanism, therefore, must first fully close the machine and then uniformly tighten the joint so as to be completely leak proof. The idea of stringing the swing bolts on a shaft so that all are operated simultane-

ously is the starting point of the mechanism. Making this shaft eccentric in the bearings is the cardinal feature of the tightening arrangement, for then the simple rotation of the shaft tightens or loosens all the swing bolts depending upon the direction of rotation. The swing bolts when loosened must, however, be lifted out of the way so that the lower half can swing back. Steel pins threaded into the shaft impinge upon lugs on the bolts and the continued rotation of shaft lifts each bolt out of the way. The amount of eccentricity in the shaft is usually a maximum at ⅜ in., so that some auxiliary means is required to close the gap at the front. This is taken care of by a king bolt in the center. This bolt does not hang on the shaft like the others but rides on cams secured to the shaft. The design of these cams allows the king bolt greater play than any of the other bolts and is sufficient for it to engage the lower half. Therefore, in opening the filter all the others unloosen and are lifted away from the shell, while the king bolt holds the weight of the lower half and is still in place. The load of the lower half is then taken up by the hydraulic cylinder before the king bolt is swung out of position. This is effected by the engagement of a pin on one of the cams with a lug on the bolt. The special curvature of the cams takes care of the action of the king bolt when all of the other bolts are released from holding the lower half, but when the bolts are in engagement the cam curve is a circle. Then, it operates in unison with the others and helps tighten the joint. Simultaneously pulling on thirteen bolts so as to compress the gum-strip gasket requires considerable power, but by back gearing the shaft to the rotation of a pilot wheel plenty of leverage is provided, so that one man can comfortably tighten the joint.

Internal Manifold Pipe.—Outside of the Merrill Filter Press the Sweetland Filter was the first to incorporate sluicing discharge. The internal manifold pipe is primarily a sluicing pipe and is the basis of the sluicing mechanism in Sweetland Filters.

In many installations this internal manifold is also the overflow pipe, collecting liquor evenly through each nozzle located between the leaves. For this work the internal manifold is ideal for agitation within the filter.

The pipe is generally a standard extra heavy pipe and is located in the longitudinal cavity of the upper half. It projects through the casting and is carried through external stuffing boxes. Generally the sluicing water is fed through both ends, although when used for overflowing only one end may be capped. The sluicing nozzles are short nipples threaded into the pipe and should be of a size so that the total area of the nozzles is less than the combined area of the sluicing feed lines. When used for overflowing, especially when fibrous material is present in the liquor, the sluicing nozzles may be removed so as to reduce plugging up the holes.

The pipe being carried through stuffing boxes is rotatable and likewise capable of longitudinal motion. To facilitate the sluicing operation a self-reversing mechanism has been perfected. This is shown in Fig. 59.

Filter Leaf.—The design and construction of Sweetland leaves are probably more varied and distinctive than that of any other filter. The specifications call for a rugged construction, light weight, sufficient drainage, and uniformity so as to be positively interchangeable. Ruggedness in terms of that capable of handling and transporting is the ruggedness referred to, for to endeavor to make leaves capable of withstanding the warping action of an over-charged press would be like making a

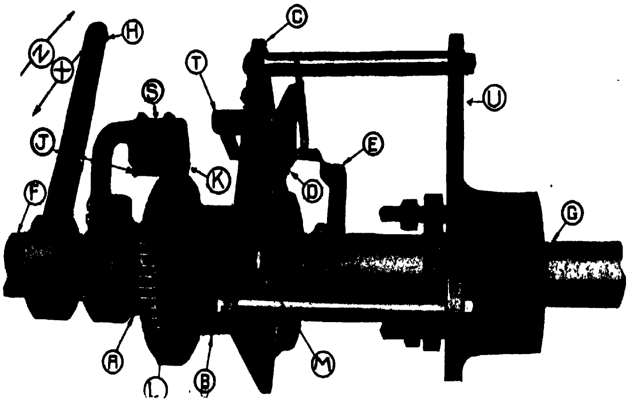

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FIG. 58.—Sweetland Filter—Automatic Sluicing Mechanism.

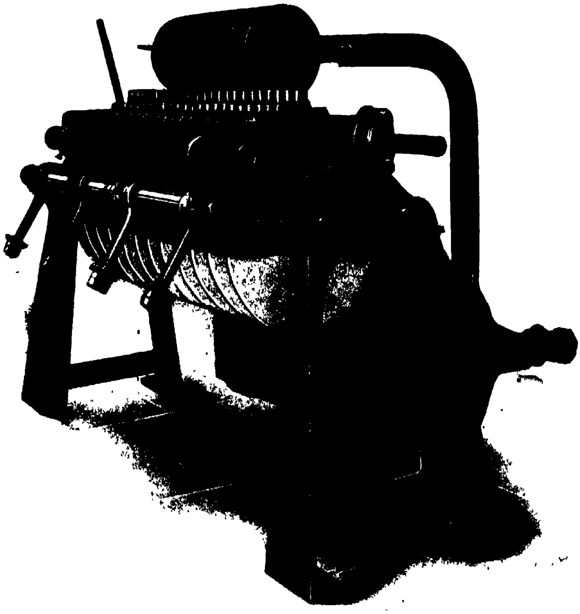
Key to Parts: A.—Transversing screw fastened to pipe. B.—Screw housing carrying flanged Ratchet M and friction rim L. C.—Spacer Plate. D.—Double Ratchet Pawl. E.—Dog clamped to pipe. F.—End of pipe projecting into expansion joint. G.—End of pipe running through filter body. H.—Sluicing handle fastened to pipe. J.—Friction Bar held against rim L by springs in head of arm S. K.—Projection on end of friction bar to trip T. L.—Changeable friction rim. M.—Flanged ratchet. S.—Arm carrying friction bar J which is forced against rim L by springs in head of arm. T.—Reversing Lever. U.—Stuffing box plate which bolts directly against end of filter.

The mechanism operates to give a definite longitudinal travel of a fraction of an inch either side of the center of each leaf until the nozzles reach a set maximum position, when the direction is automatically reversed by tripping the double ratchet pawl "D."

bumper on an automobile that would not bend if the car collided with a large tree. Light weight is a factor in handling the leaves, especially when putting them in and removing them from a filter. Sufficient drainage is obtained in double crimped screen and providing adequate outlet to the delivery pipe. Interchangeability of leaves is paramount and a feature of Sweetland Filters and, consequently, each leaf is made to template and will vary from another in thirty seconds of an inch only.

The start of Sweetland leaf manufacture is the U sectioned rim. This is made from steel flats, which are made into U shapes and then

formed into true circles. The drainage member, generally of heavy crimped wire screen, is cut to size and fitted into the rims. This is then fixed by riveting through sides of U shapes, or spot welding at a few points around the periphery. The leaves are now ready for the outlet fitting. This is a combination of cast-iron spud and sheet metal stamping welded together, the whole being attached to the leaf by spot welding.



Courtesy United Filters Corporation

FIG. 59.—Sweetland Filter—Open.

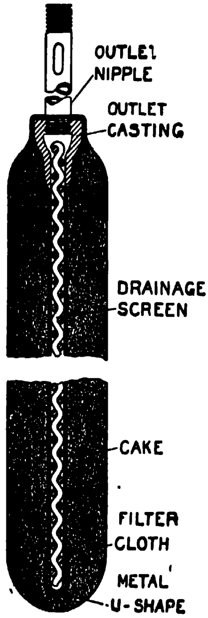
When filter is mounted on concrete supports so that the gasket surface is "eye high" every square inch of the filter surface is easily inspected. The rotatable sluicing pipe is located on top of the filter behind the leaf cap nuts and extends out of the ends of the shell through stuffing boxes.

This construction is all done on automatic machinery, saving the assembly and welding, so that each part is capable of quantity production and interchangeability.

The standard type of leaf is that described above but in order to get a leaf from which all the filtrate could be drained, a bottom drainage leaf was designed. This has a flattened tube extending to the bottom of the leaf. The exit for the filtrate is up through this tube. The specifications are otherwise like the standard leaf.

One of the clever details of design of the Sweetland leaves is the

outlet nipples. This is a standard pipe threading into the outlet spud and terminating in another standard thread onto which the top cap nut is screwed. Having the outlet nipple replaceable means that a crossed thread, or otherwise damaged thread, does not mean a discarded leaf. The unique part of the design, however, lies in the outlet for the filtrate. Holes are drilled through the pipe at a point opposite the outlet fittings of



Courtesy United Filters Corporation

FIG. 60.—Sweetland Filter Leaf with Cake—Cross-section.

Each Sweetland leaf is light and easy to handle. The metal U-shaped periphery provides both drainage and stiffening to the crimped wire screen drainage member. The outlet nipple threads into the outlet casting which is secured to drainage screen and to the U shape by spot welding. The filter cloth envelops the assembled leaf and by reason of the free drainage through the screen even cakes are built up which are easily washed and discharged.

the machine when the leaf is in the filter. This is surely a simple means of getting the filtrate out of the leaf and into the collecting manifold and yet most positive.

Putting the filter cloth on the leaves has never been improved from that used in the early stages. The bag is sewn halfway round by machine, turned inside out and the leaf inserted. The upper half of the bag is hand sewn but the sewers get as proficient as the old time sail makers and cover a leaf in less than 10 minutes. When the leaves are to be used

in machines requiring dry discharge by reverse current of compressed air, hollow eyelets are riveted through the leaves on 6 or 8 inch centers so as to prevent excess ballooning of the cloth.

Operation.—The principle of operation for Sweetland filters is practically identical with Kelly filters and similar to suction leaf filters.

Leaf filtration is well defined as the reverse of bag filtration. With the latter the muddy liquor is applied to the interior of the bag and the filtering force drives the liquid to the outside, the solid accumulating on the inside. In other words, bag filtration is from the inside out. In leaf filtration the liquor surrounds the outside, the filtrate is forced into the inside and the solids accumulate on the outside. In truth, filtration is here, "from the outside, in."

It has also been pointed out that pressure leaf filtration is a modification of plate and frame press operation. If the filtration in plate presses is arrested before the cakes touch each other, the cake formation is identical with that obtained in pressure leaf filters. Leaf filters are in this sense mechanical modifications of plate and frame presses.

If the leaf is the fundamental of Sweetland filters, cake formation is the vital factor in their operation. Sufficient cake must be formed to insure complete discharge. Too much cake must not be formed or washing and discharging are jeopardized.

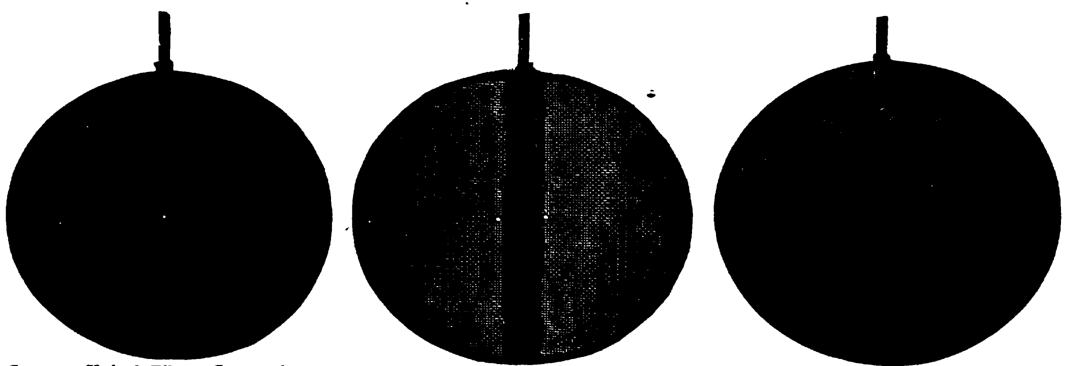
In cake forming the initial operation is to fill the filter with liquor and to vent the air contained in the pipe lines and machine. It is positively poor practice not to release this air, for then the air must be vented through the filter cloth, which means a back pressure so that filtration starts on the submerged parts of the leaf in advance of the upper sections. Also, it is physically impossible to vent all of the air through the leaves so that cake formation at the top of the leaf may be further retarded. Uneven cake formation is bad practice in Sweetland filters.

If uniform thickness of cake is required, it may be found necessary to provide agitation within the filter during the cake building when handling liquors, the solids of which tend to quickly classify. This is conveniently obtained by overflowing some of the liquor through the internal manifold.

Cake building progresses until the cake thickness reaches the economical limit. This is determined by previous experimentation or by past plant experience. In brief, it is the point beyond which the amount of filtrate obtained in the time expended is less than that obtainable by running more cycles through per day. Not having to form hard cakes, as in plate and frame press operation, makes this phase of the Sweetland filter operation distinctly advantageous.

Cake building is followed generally by withdrawing the excess unfiltered liquor lying about the cakes in the drainage channel and overflow cavity. It is possible in some installations to follow cake building with cake washing without withdrawing the excess, but such cases are exceptions rather than the rule.

The excess must be withdrawn quickly, but there must always be



Courtesy United Filters Corporation

FIG. 61.—Sweetland Filter Leaves.

Top Drainage, Uncovered. Bottom Drainage, Uncovered. Top Drainage, Covered.

The light, sturdy character of Sweetland leaves are prominent features. When necessary to reduce the filtrate lying within the leaf at close of the filtering or washing cycle, the bottom drainage leaf is used. A flattened tube extends to the bottom of the leaf and has an opening at its base only. When reverse compressed air balloons the filter cloth excessively the cloth is secured to the drainage member on 6-inch centers by hollow rivets which extend through the screen and hold both sides of the cloth.

positive pressure within the machine so as to hold the cake on the leaves. In consequence, coincident with closing the liquor valve, compressed air should be admitted to the shell and the drain valve opened.

Promptly after the liquor is drained from the machine, the filter is ready for the next operation. This may be to dry the cake or to discharge it, but more often it will be to wash the cakes free of the entrained solubles. Therefore, simultaneous with closing the drain valve the wash water valve is opened, the compressed air valve closed, and the air vent cracked. The operator now watches his pressure gauge and vents the air so that the pressure is maintained at 5 to 10 lbs. per sq. in. The wash water should be fed at a rate so that a maximum of 3 minutes is required to fill the filter with water. When water issues from the air vent the operator knows his filter is filled with wash water and can now close the air vent.

Until very recently the practice has been to use clear water for washing the cake. The idea has been that clean water assured against any enrichment or contamination and when washing to neutrality, or to low percentages, the water must be neutral or pure, or as much soluble will be entering the cake as is being extracted.

The writer has proved, however, and without a single exception, that clear water is poor practice. Clean water muddied with some washed solids from a previous run, or with some inert solid, will wash the cakes better in every respect than plain clear water. The theory is positively sound and cannot fail to work. The whole secret of displacement wash is the equi-resistant surface of the cakes. It is physically impossible to make a transfer of unfiltered liquor from a Sweetland, or any other pressure leaf filter, and maintain an absolutely equi-resistant surface on all the cakes. Partial drying, or cooling of the unsubmerged parts, changes the filtering resistance to those parts longer submerged. Where clear water passes through such cases paths of unequal resistance to its passage are set up and excess wash water and time are required if the discharged cake is to contain only the allowable soluble content. The solids of the muddied wash waters are filtered out and offer a resistance to the flow. As more water penetrates the cake more solid accumulates, more resistance is set up until the positively equi-resistant surface is regained. The amount of solid is determined locally and largely in relation to the rate of flow during washing. If this is high, the solid content can be greater than if it is low. In the majority of installations the rate of flow on washing increases as it progresses, due to the extraction of a viscous or dense liquor and substituting a more fluid wash water whereby the cake resistance decreases. This means, therefore, that the time extension required with a muddied wash water is trivial and negligible.

It is interesting to note the attendant advantages of the muddied wash water. Drying cakes in leaf filters is primarily dependent on the volume of the voids in the cake. If the cake is dense and the voids low the compressed air can effectively remove much of the liquid. Compacting the cake is obtained only by higher pressures than employed during cake

building. Without muddying the wash water, increasing the pressure of washing intensifies unequal washing so that better drying is obtained at a sacrifice of the washing efficiency. With solids suspended in the water the pressure can be increased with absolute freedom, as irrespective of the pressure the equi-resistant surface is maintained. Also, it was found that when handling an organic liquor, a 1/4 in. cake was an economical maximum, but by having washed solids in the wash water, a cake 3/8 in. could be built up easily and the latter offered no trouble in automatic dry discharge, while sluicing was the only way to get rid of the 1/4 in. cake. The scheme, simultaneously, aids washing, drying and discharging, to a greater or less degree with every installation.

Washing the cake is completed when the operator finds his wash filtrate tests to the limit set for him. This may mean hydrometer readings, neutrality with litmus or other indicator titration, or by color. Time control on washing is practiced in some plants but generally because excess sweet water can be handled without evaporation. Leaving the matter of shutting off the wash water to test by the operator is, of course, putting the control directly in the hands of the operator, but it is significant how the average operator feels this responsibility and lives up to it. Some plants have put the filter foreman in charge of mixing the batches and evaporating or handling the filtrate and inaugurated a system of bonus and demerits on cake analysis. Such an arrangement insures the right sort of control and high filter efficiency.

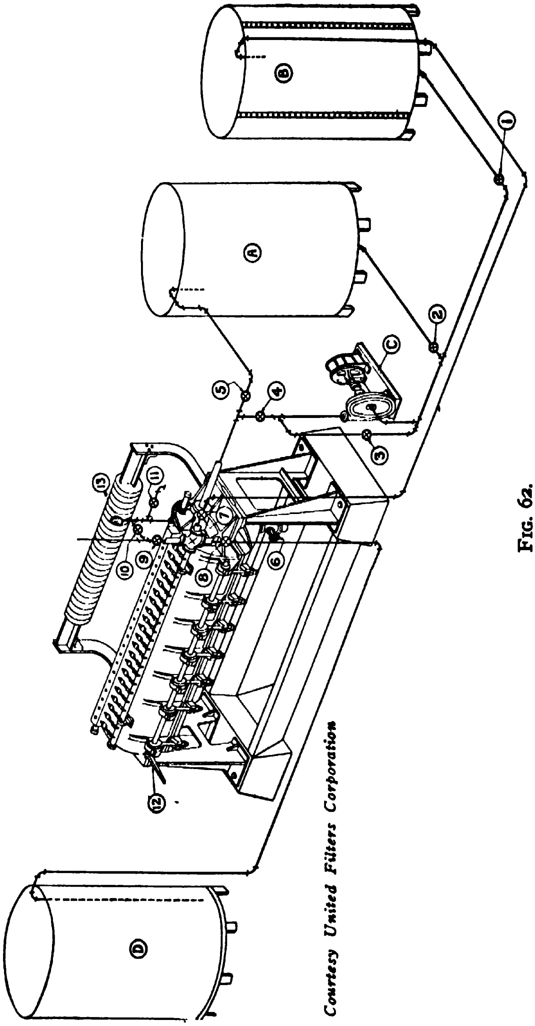
When washing is concluded, the excess water must be drained from the machine and the same care is required as when draining the excess unfiltered liquor.

Washing is usually succeeded by drying. Even where the cake is run to waste it is good practice to dry it for a few minutes, as this tends to force out all liquor within the leaves and outlet pipes, the soluble content in which will often more than pay for this work.

Drying in Sweetland filters is accomplished by filtering compressed air through the cake and displacing the liquid in the cake. Substituting a gas for the liquid in the voids of the cake allows the particles of the cake to assume new positions and, as the tendency is toward closer formation, the contraction in volume produces cracks in the cake. At this point further drying is waste of compressed air. Good drying effect is, therefore, dependent upon delayed cracking of the cake. Cracks are delayed when the voids of the cake are small, due to good compacting of the previous cake building and washing operations.

It is essential that the withdrawal of the excess wash water be as quick as possible so that the cakes maintain as near an equi-resistant surface as possible. The pressure during withdrawal should not be higher than necessary to keep cakes on the leaves.

Discharging follows the drying operation. Experience has proved that discharging during cake building, with the idea that discharged cake will fall to the bottom of the filter and leave cleaned filter cloth for further filtration, is impractical. Only complete discharging is effective and



Courtesy United Filters Corporation

FIG. 62.

FIG. 62.—Layout Sweetland Filter—Dry Discharge.

1.—Valve controlling supply of pulp to be filtered (this term pulp refers to a mixture of solid and liquid). 2.—Valve controlling supply of water for washing soluble matter out of filter cake. 3.—By-pass valve. 4.—Main feed valve to filter. 5.—Valve for withdrawal of excess wash water from filter. 6.—Drain-off valve to be opened before opening filter for cleaning. 7.—Cloudy filtrate valve. 8.—Clear filtrate. 9.—Compressed air for discharging cake (5 lb. pressure). 10.—Valve for admitting compressed air to filter body. 11.—Vent valve. 12.—Swing bolt handle (for locking filter). 13.—Pressure gauge.

A.—Supply of hot or cold water for washing filter cake to extract solubles. B.—Tank containing main supply of pulp. C.—Centrifugal pump for handling pulp and wash water. (Note that if pump used at this point is capable of exerting more than 50 lbs. pressure per square inch on the filter, a relief valve should be installed in the main feed line between valve 4 and the filter, and this valve should be set for 50 lbs.—the maximum operating pressure of the filter.) D.—Tank for clear filtrate.

A cake hopper is shown beneath the filter, arranged to connect with a chute or suitable conveyor for taking away the cake as it is dumped from the filter. The sluice pipe is capped off at both ends and no sluice pipe handle is used.

The essential of a well-designed layout is the convenience of valves that must be operated simultaneously. Where impractical to locate all valves in a cluster those valves which must be opened coincident with the shutting of another should be close together.

this is practical only when plenty of room is provided for the disengagement of the cake.

The Sweetland filter was the first pressure leaf filter to be operated as a sluicing discharge machine. As such the filter is not opened as the cakes are broken up and flow away as solids suspended in the sluicing water. Sluicing is effected by the projected streams of water under high pressure issuing from the nozzles in the internal manifold. These streams are designed to project at right angles to the manifold and apparently parallel to the surface of the leaves. The streams, however, really baffle from one leaf to the adjacent leaf and have sufficient force to cut the cake. The manifold is rotatable and capable of longitudinal motion so the streams are made to sweep across every square inch of filter surface. With some materials, discharge is aided by putting reverse compressed air into the leaves while sluicing. Steam is seldom used nowadays as the sluicing water condenses it too freely. Different plants hold different views as to the value of pinning the cloths to prevent ballooning. Some claim that the baffled streams chatter an unsecured cloth and that this helps disengage the cake. Others hold that the purging action of reverse compressed air is too valuable to lose and pinning the cloths prevents ballooning that would otherwise block the sluicing streams from reaching the lower sections of the leaves.

Dry discharge from the Sweetland filter is more positively obtained than with any other pressure leaf machine. First, by having the leaves stationary and the lower half swinging from a longitudinal axis, prematurely discharged cake does not harm the leaves. Second, by opening the filter so that every square inch is observable, there is but little excuse for a filter being but partly cleaned. The operator is to blame for a poorly discharged filter.

Reverse current of compressed air is the standard means of discharge. Steam can be substituted for materials that are difficult to disengage from the leaves as the condensed steam often lubricates the surface of the leaves and aids discharge. Reverse water is seldom effective unless the filter is closed and the water level allowed to rise. This, of course, is no longer dry discharge and if such measures seem necessary it is a good indication that the filter cloth used is too dense.

It will often happen that the bulk of the cake is discharged but parts of the cake refuse to fall off. Time is saved by taking a long handled paddle and dislodging these by hand.

The time required for discharging varies with the material, but with good operation it should not exceed 5 minutes. It is, however, time poorly saved to restart the filter without first inspecting and making sure all the cake has fallen.

Layout.—The proper set up of filter piping layout and arrangement of valves has been given the consideration worthy of this detail.

The factors resulting in success or failure of an installation are many times small and presumed inconsequential. The matter of a leaky inlet valve has been known to cost a plant more than a hundred tons of coal in the evaporation of excess sweet water. Failing to mount the

filter on high enough foundations prevented the operator from conveniently inspecting the filter after discharging and inadequate discharge accumulated until the leaves were warped out of shape, when washing results were very poor and discharging worse. Convenience of valves for simultaneous operation is always imperative in handling pressure leaf filters, and if some of the control valves are out of reach, the cleverest operator in the world could not get the best out of the machine.

In light of the above, the layout recommended by the manufacturers is not an ideal arrangement furthered by them but the correct set up as found by years of experience. It should be followed with as little deviation as possible.

The cardinal essentials in erecting a Sweetland filter installation are (1) To mount the filter so that the joint of the two halves is "eye" high from the floor or operating platform; (2) that pipe lines be amply large especially drain lines; (3) that valves and gauges shall be convenient to the operator; and, (4) that the operator shall be able to observe filtrate discharge and, where practical, the levels in receiving tanks, so as to prevent overflowing the tanks.

Advantages.—As a leaf filter, the Sweetland Clam Shell Filter embraces all the advantages of the leaf system and by reason of the mechanics employed obtains these advantages to a greater extent than is obtainable in any other leaf filter. The general mechanical arrangement is, therefore, the leading advantage of Sweetland filters. In no other machine are the details of convenience for the operator so well worked out. This is the ground work on which so many attendant advantages are dependent and are made possible.

The paramount advantage of leaf filters is the washing of the cake by displacement although the popular advantage is the labor saving. The even distribution of wash water with the minimizing of excess space accounts for the better washing results obtainable on the Sweetland filters.

The equal area of the filter leaves, and the consequent even distribution of the reverse compressed air largely accounts for the automatic discharge of the solids with the minimum hand labor. Sluicing the solids from the leaves is possibly the acme of automatic discharge from this type of filter and a distinct advantage this machine holds over all others.

Their wide adaptability and convertibility is another feature of Sweetland filters. Ability to cease filtration at the economical limit of flow, rather than having to wait for the cakes to build solid and the ease of discharging the cake, make the Sweetland a well-nigh universal filter. Taking out intermediate leaves and plugging up the openings with stop-off bolts converts a Sweetland filter from a small caking machine to one adapted to handle heavy cakes.

Having all the leaves of the same size and interchangeable means that any spare can be substituted for any faulty leaf. There are more leaves for a given filter area than is required in a Kelly filter, so that each leaf is light and easily handled by one man. The ease of removing and replacing the leaves makes it practical to substitute a spare for an

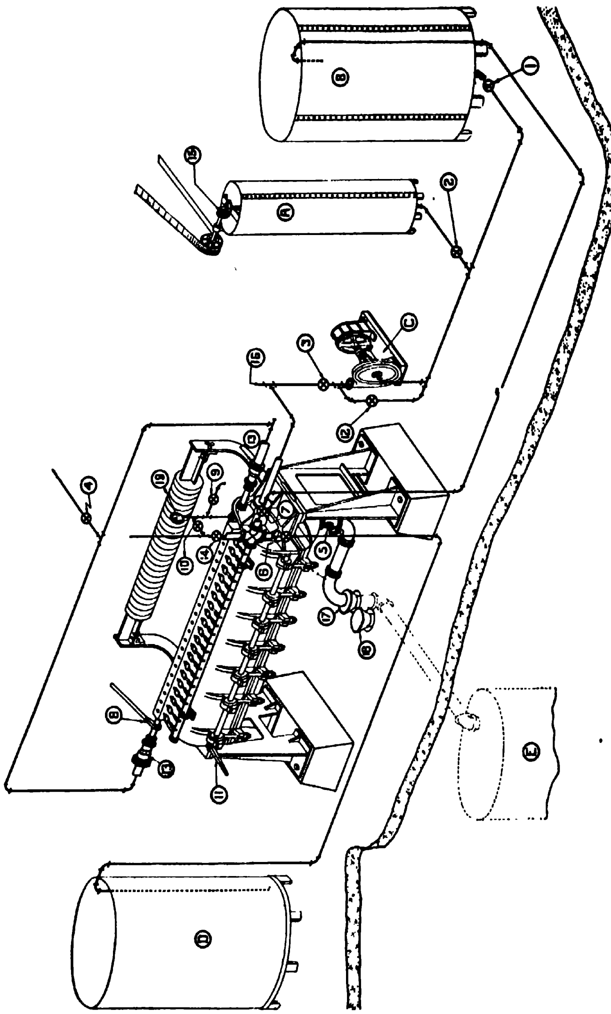


Fig. 63.

Courtesy United Filters Corporation

FIG. 63.—Layout Sweetland Filter—Sluicing Discharge.

1.—Valve controlling light filter aid liquor. 2.—Valve controlling heavy filter aid liquor. 3.—Inlet valve to filter. 4.—Sluicing water valve—water pressure 70 to 80 pounds per square inch. 5.—Drain valve for unfiltered material and sluicings. 6.—Clear filtrate valve. 7.—Cloudy filtrate valve. 8.—Sluicing handle. 9.—Vent valve. 10.—Compressed air valve (5 lb. pressure). 11.—Swing bolt shaft handle (for locking filter). 12.—By-pass valve for returning excess unfiltered material. 13.—Expansion joints. Note that on 31" and 37" filters no expansion joint is required for left-hand end of the filter as shown on the drawing as a special fitting is supplied with the filter. 14.—Compressed air valve to assist in cleaning filter bags (pressure 5 lb. per square inch). 15.—Agitator. 16.—Blanked connection used for water inlet in special work where a cake is washed. 17.—Drain for excess unfiltered liquor. 18.—Drain (to sewer(for sluicings. 19.—Pressure gauge.

A.—Tank for holding liquor mixed with filter aid. This tank of the same height as tank B and of such a volume as to accommodate approximately two to three times the amount of liquor required to fill the body of the filter. B.—Main portion of liquor to be filtered. C.—Centrifugal pump capable of handling from 30 to 50 pounds pressure per square inch in the filter.

Note that where another style of pump is used care must be taken to see that the normal operating pressure, i.e., 50 lb. per square inch—on the filter body is not exceeded. With direct acting plunger pumps, or the like, we would strongly recommend the insertion of a relief valve on the main feed pipe just before it enters the filter body. D.—Tank for clear filtrate. E.—Tank for excess unfiltered liquor. This tank and the dotted piping are only recommended on large installations. Where several filters are operated and a common tank E can be used to take the excess from the whole station, a pump or other means of raising material from tank E to tank B must be provided. Where several filters are installed in a battery the piping and arrangement of tanks, etc., can be considerably simplified.

The sluicing arrangement distinguishes this layout. Sewer drains should be used with the caution that positive control (locked valves, etc.) be assured so that only waste liquors are drained to the sewer.

imperfect one and an easy job to remove all the leaves when they need removing.

With the gasket joint elevated "eye high," the opened filter can be inspected most conveniently by walking along the machine. Every square inch of filter cloth can be searched to make sure all cake has fallen and with a long handled paddle any remaining is easily dislodged. This accessibility to the filter cloth is a practical advantage of far-reaching importance.

Having the leaves fit comparatively snugly to the shape of the filter, and otherwise reducing the excess space within the filter, makes the transfer of unfiltered liquor a short operation reducing the hazard of losing the equi-resistant condition of the cake. Where uniform cakes can be counted on run after run, this reduced excess liquor makes possible the simplest washing operation of any leaf filter or filter press, by introducing the water without draining.

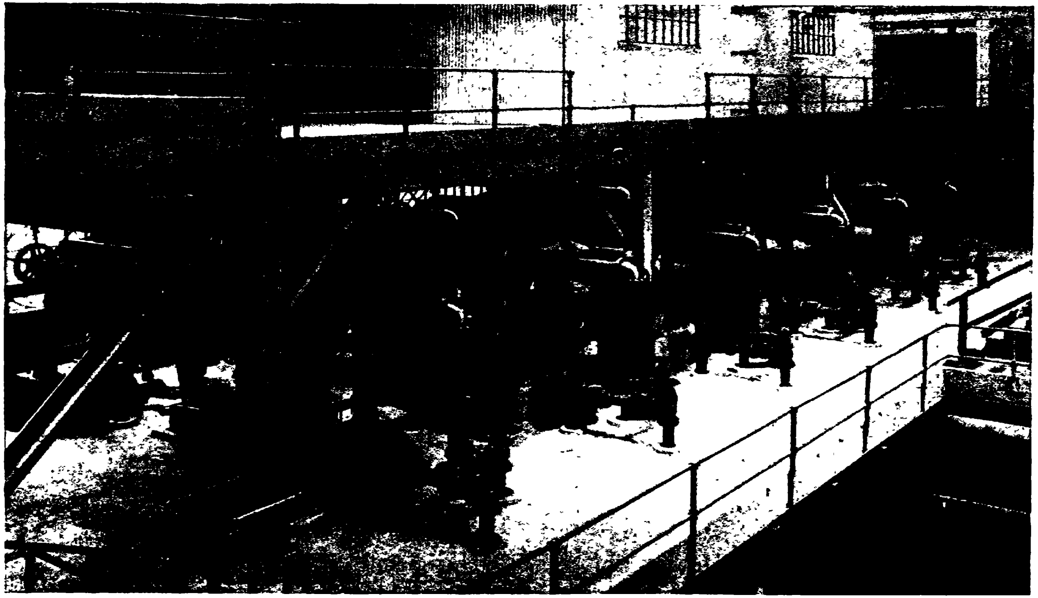
The quick opening, positive gasket joint, individual control of the filtrate from the leaves and the compact let up of this filter are unsurpassed in any modern filter.

The stationary leaves and the movement of the opening lower half away from the leaves gives the Sweetland a big advantage over the Kelly when handling thick cakes which fall from the leaves when the pressure in the filter is released.

The absence of moving parts makes possible lining the Sweetland with chemical lead to prevent corrosive attack, although this lining is a bigger success when handling cold liquors than with hot materials. This feature is unique in pressure leaf filter design.

Drawbacks.—The operation of the Sweetland is cyclic and therefore intermittent. A machine capable of continuous operation has inherent advantages over intermittent operation. This can be called a drawback to the Sweetland filter, but it must be borne in mind that few continuous filters are now working on more than ⅓ submergence which means that for ⅔ of the working time they are not filtering. Thus, it is possible to operate Sweetland filters with the time of filtration greater than ⅓ of the total cycle when the actual filtering work of each square foot of filter cloth is greater than with continuous filters. Again, pressures in excess of those obtainable with vacuum filters are used in the Sweetland and, with some materials, this gives a greater flow per total cycle than that obtainable in continuous. Offsetting this, however, continuous filters are filtering for a much shorter period and, consequently, within the high points of the rate of flow curve making their production more efficient. Also, for the majority of materials handled in industrial work, 10 lbs. per sq. in., or 20 in. of vacuum, is quite enough filtering force to get a high output.

The actual labor involved in the operation of a Sweetland, or a battery of Sweetland filters, is not a big item per ton of output and does not give a big advantage to continuous filters. However, the operation is dependent upon the personal efficiency of the operator and in this respect continuous filters have an advantage over the Sweetland. This



Courtesy United Filters Corporation

FIG. 64.—Battery of Sweetland Filters.

When substituting Sweetland Filters for bag filters in sugar refineries the cleanliness of the station is in strong contrast with the conditions obtaining with bag filters. Each filter is an independent unit with its own control valves, the arrangement of which, however, is similar for each unit.

point is emphasized in each detail of the cycle. Failing to check filtration before the cakes build together depreciates washing and discharging the cakes. Stopping cake building too soon leaves too much excess liquor and the cakes may not have enough mass weight to discharge well. Failing to transfer the liquors properly means losing the equi-resistant cake. Stopping the washing too soon leaves soluble in the cake. Washing too long means excess weak liquor. Discharging should be automatic but, if not followed by thorough investigation and dislodging any cake remaining, succeeding runs show lower results. This control is not required of an operator with continuous filters.

The means of drying the cake in Sweetland filters is not comparable with the cake compression in plate and frame filter presses, or with continuous filters equipped with filter cake compressors. This deficiency is one of the greatest drawbacks to the Sweetland filter tending to narrow its field of application to those cases where the solid does not have to be subsequently dried to a powder.

Applications.—The Sweetland filter has been applied to such a variety of materials and uses as to well deserve the title of the universal modern filter. It has, however, particular usefulness in a few fields where it tops all competitors and where its advantage is likely to be continued.

In handling liquors heated close to the boiling point, or other volatile liquors, the Sweetland is the superior filter now on the market. There are no hot plates and frames to handle as in the case of the plate and frame press on this work and no vaporization troubles as exist in vacuum filters.

For supersaturated, or scale forming liquors the Sweetland filter installed with a back pressure on the leaves cannot be approached. A closed delivery plate and frame press is not comparable to an open delivery press and no progressive plant will use a plate and frame machine where a Sweetland can be installed. Vacuum filters are out of the question for this duty.

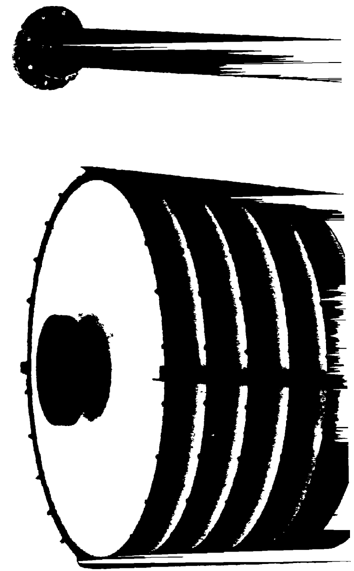
Where sluicing discharge is permissible the Sweetland is far and beyond all others as a clarifier of those industrial liquors containing a relatively low solid content and resistant so as to preclude long filtering cycles. The ease of discharging by the automatic sluicing mechanism is in contrast with the miserable job of cleaning plate and frame presses on this duty. It may develop that vacuum discharge coupled with high submergence may compete with Sweetland filters on this work, but, at this writing, such is not a commercial and demonstrated success.

Sweetland filters still maintain a hold on all fields in which exacting wash of the cake is required. To see so many of these filters failing to hold their own in the beet sugar industry is not encouraging, but in each instance where washing is no longer attempted, the filter being used as a clarifier and thickener only, washing would still be a success if a muddied wash were used. It is to be expected that muddying the washing liquid will allow these filters to regain their reputation as displacement wash machines and this will not only maintain their fields but increase them as well.

Summary.—The excellent results obtained with Sweetland filters wherever installed in competition with frame presses established the value of pressure leaf filters. In the beet sugar field uneven cake formation became chronic in some regions so that Henri Vallez, as superintendent of a beet sugar plant, hit upon the idea of rotating the leaves during the filtering operation, when the unevenness would be distributed around the periphery of the leaves. Upon this idea he developed the Vallez filter, which is the subject of the coming chapter.

are the leading features of the design. The shaft is a piece of very heavy tubing key seated for a length equal to the overall length of the leaves when assembled. Holes are drilled through to allow the filtrate from the leaves to feed into the shaft. The leaves are mounted on cast-iron hubs which slip over shaft and are held rigid to the shaft by being keyed to it. These hubs are made of varying widths corresponding to the leaf spacing and abutt one another as companion flanges. The entire set of leaves are clamped together by couplings on each end. Positive alignment is provided by means of four angle irons bolted to the periphery of the leaves at 90 degree intervals.

The leaves, or rather the bare frames, are made extra rigid so as to insure positive plane surfaces and to eliminate any tendency toward warping. Flat surfaces are easier to clean—the secret of the good discharging obtainable from this filter. Instead of using one screen these leaves are made with two perforated plates separated by a coarse screen. This combination gives admirable drainage and a smooth surface over which the filter cloth is laid and clamped to the frame.



Courtesy Vallez Rotary Filters

FIGS. 65 and 66

All the leaves are strung on the interior. The rigid leaves are sepa agitator paddles.

In order that the leaves shall be rotatable the shaft is flanged to extensions which pass through stuffing boxes in the shell and terminate at one end in a male and female expansion joint and at the other in a closed end to which the worm gear is fixed. The stationary member of the expansion joint is fitted with the customary outlet connections and piping for reverse current, etc.

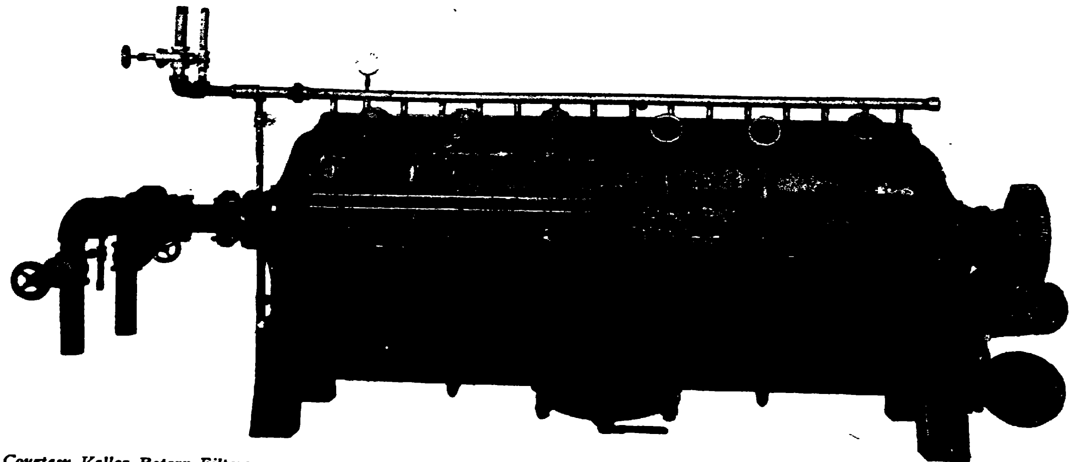
After the filtering element the next distinctive feature is the discharging mechanism. This is principally a screw conveyor located in the bottom of the lower part of the filter, one half of the conveyor being right and the other half left hand, with the rotation such that the cake is carried to the center of the machine. Here a large opening is provided, the cap of which is a modified manhead cover capable of being quickly opened or shut. The trough receiving this conveyor does not sweep up the sides of the machine as the aligning angles are effective feeders of cake to the trough.

The shell of the machine is divided longitudinally on the center axis. Since the machine is not opened for discharging, the gasket joint is made up with standard bolts. The upper half is removable and the lower half stationary. When removing the upper shell a chain fall or other hoist mounted on a mono-rail trolley is brought over the machine and lifts the shell up and away from the filter. This exposes the entire filtering element and with the hoist it can be disconnected and removed.

The observation doors in the upper half are interesting. These consist of two hinged plate covers and are held pressure tight by quick closing swing nuts fitted with circular handles. These are conveniently opened and give the operator a chance to inspect the progress of the discharging operation as effectively as though the whole filter were opened. This is truly a simple scheme but the mechanics are as truly ingenious.

Inasmuch as the leaves rotate the specifications of a sluicing pipe are very simple. The throw of the sluicing water is only one half the diameter of the leaf. The nozzles do not need to move and each side of the leaves can have a separate nozzle playing upon it. The sluicing pipe can be located at the zenith of the travel, so that gravity works in line with the eroding effect of the water jets. For dry discharge compressed air, or steam, dislodges the cake from relatively free filtering material making possible an approximation to dry discharge.

Another simple, but clever detail, is a continuous density tester. When washing sugar juices or other solubles from the cake the progress of the wash is determined by sampling the filtrate in a flask or graduate and reading a hydrometer spindle placed in the liquid. There is danger of breaking a hydrometer just when it is needed most and there are other annoyances that make it worth while to obviate this nuisance. In designing a continuous sample it is necessary that the liquid shall be a true sample of the filtrate flowing at that instant, it being necessary that the velocity of flow shall not affect the buoyancy of the spindle and that the spindle shall not adhere to the side of the receptacle and thus



Courtesy Vallez Rotary Filters

FIG. 67.—Vallez Filter—Observation Door Open.

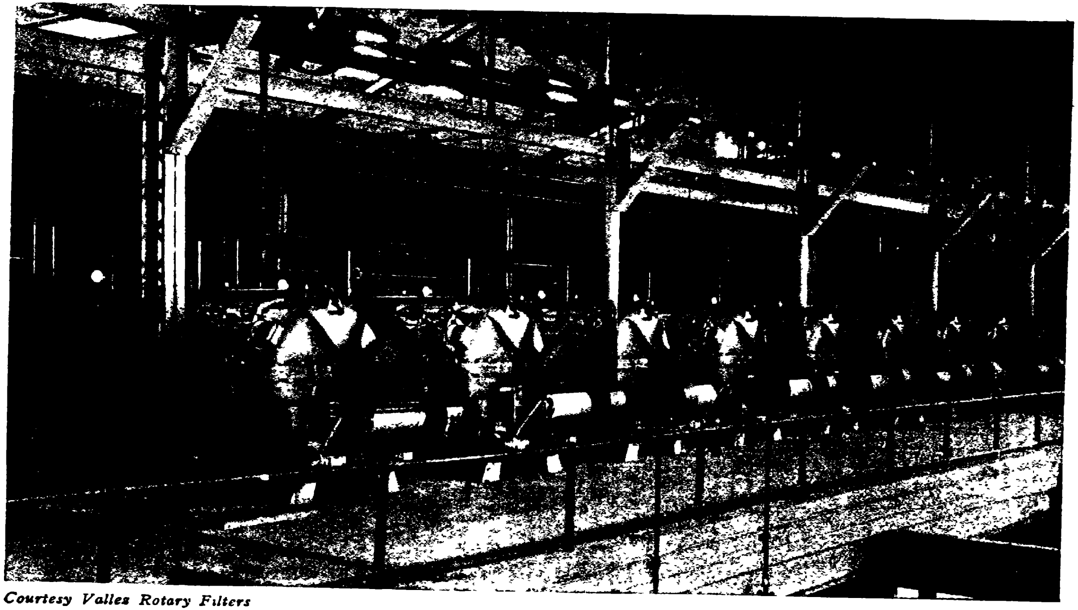
Heavy construction marks the mechanical design of Vallez Filters. The filter leaves are rotatable through an external worm and worm gear. The discharge of the cake is observable through the openings provided under the observation doors. The discharged cake is propelled to the center of the filter and dropped out of the manhead at the bottom.

influence the reading. These specifications have been covered in the Vallez filter by taking a small pipe connection from the under side of the filtrate out to the tester proper. The tester is located with its overflow, which bleeds into the liquor tank, at about one foot under the filtrate shaft, thus providing head for the continuous supply of fresh filtrate. The diameter of the test pipe is of sufficient increased diameter over the diameter of the sampling pipe to reduce the velocity and still of small enough volume that its contents change quickly. The overflow from the internal testing tube is caught in a circular outer trough to which the overflow line is connected.

The cake tester used in the Vallez filter comes closest to being a true indicator of the cake thickness of any ever devised and tried out. Its principle is simplicity itself, i.e., the outward movement of a paddle resting on the cake as the thickness of the cake increases. This movement is magnified by the deflection of an indicating needle located outside the machine. A calibrated scale behind the needle reads directly the cake thickness and is a most convenient guide to the operator. The successful operation of this indicator is in contrast to those tried out in other filters. The secret of success lies in two main factors, first, the paddle truly rides on surface of cake; and second, the filter medium is more representative of total area. With stationary leaves any automatic indicator depends upon the cake growing in excess of the distance between filter cloth and the setting of the indicator's plate. When the cake exceeds this distance there is set up a difference in pressure on the exposed side of the plate and the packed side. This excess pressure forces the plate into the cake and this movement is that used for indicating to the operator the end of the cycle. But this indicates the cake at one point only.

The positiveness and accuracy of such indicators is a function of the resistance set up by the material being filtered and, consequently, works better with some slurries than with others. In the Vallez filter, the paddle is set against the filter leaf and is forced away from it as filtration progresses. This action takes place because the cake is constantly moving under the paddle and pushes the paddle away instead of letting any cake accumulate around it and force it inwardly. Of course, if this indicator is to be equally good for hard and soft cakes, the force necessary for its movement must be slight and this has been taken care of in the design.

The other strong point in the Vallez indicator is the better cleaning of the filter cloth under the indicator paddle. In the other pressure leaf filters the operator had to clean by hand the cloth under his indicator. Depending upon the operator this might mean that the cloth was better cleaned or not as well as that throughout the machine. This variable was the cardinal weakness of these indicators. In the Vallez the indicator is situated near the periphery of a leaf and this part of the leaf is subjected to the strongest action of the sluicing nozzles and hence more assuredly cleaned. Of course, there is a possibility that the particular nozzle cleaning this leaf may be plugged, or otherwise in-



Courtesy Vallez Rotary Filters

FIG. 68.—Battery of Vallez Filters.

Not having to open the filter to discharge the cakes makes it possible to locate the filters on close centers. One overhead line shaft serves, by means of separate belts, to rotate the leaves of each filter. Head room over the filter for a hoist suspended from mono-rail enables the upper half to be removed when the filter element has to be replaced.

capacitated, when the area under the paddle is not equal to the average area in the filter.

Therefore, the Vallez indicator is the best guide devised for determining cake thickness, but for a general rule it should be considered a guide and not an infallible indicator.

Operation.—The distinctive feature of operating the Vallez filter is the rotation of the filter leaves during each step of the cycle. This simple modification has a most interesting influence on the operating features and should be contrasted with the operation of the older Kelly and Sweetland pressure leaf filters.

The initial step in cake building is filling the filter. This should be accompanied by good distribution and in this filter the inlet is a manifold having four openings into the filter evenly spaced. The filter leaves are started rotating, at a speed generally of 1½ revolutions per minute, and the four side angles function as agitator paddles helping to maintain uniform slurry. In especially quick settling materials it is possible to rotate the screw conveyor and underflow the thick material brought to the center.

When the press is full, liquor running from the vent, filtration commences. The leaves continue rotating and the filtrate flows from the central shaft to the receiving tanks.

As soon as the cake has accumulated to the economical thickness determined by experience, with the aid of the cake indicator, filtration ceases by shutting off inlet valve and turning on compressed air to top of filter. Simultaneously, the return drain valve should be opened and closed after the liquor is entirely drained from the filter. The wash water valve is turned on, the compressed air closed and the vent cracked so as to let the air out of the filter.

It is well to note what effect rotation of the leaves has had so far in the operation. First, the side arms as paddles helped agitation and this of itself decreases uneven cake formation. Next, the leaves rotating are constantly passing through such thick slurry as may persist at the bottom and such thin as remain at the top. This alternate travel through thick and thin averages very well with the slurry obtaining at the center so that the cake thickness is practically the same over the entire area. When withdrawing the excess the exposed area is above the liquor level but this continuously moves into the liquor and out again. In consequence, the air drying effect is minimized. This is, of course, equally true as the wash fills the machine.

Therefore, with rotating leaves a more uniform cake is built up and a cake freer of air cracks or other paths of short circuit is presented to the wash water. Forming and maintaining equi-resistant cakes is vital to good washing and a feature of the Vallez filter.

Washing is simply the percolation of the wash water through the cake and displacing the soluble in the cake. While the cakes in the Vallez filters approach the condition required in the application of the theory of displacement wash, still, the matter of valve control during draining is one of the individual operator's efficiency. To overcome

any shortcomings on the operator's part the wash water should be muddied with washed cake from previous runs, so that washing becomes the filtration of water from washed suspended solids. This filtration reforms equi-resistant surfaces and insures equal percolation of the wash water and hence uniform displacement of the soluble.

When the filtrate shows the desired limit of soluble, as determined by the hydrometer spindle, washing ceases with shutting off the wash water, turning on the compressed air and opening the wash drain valve. When all the water is out, the compressed air is opened up and the drain closed.

Drying the cakes is, in effect, filtering compressed air through the cake. Note that the rotating leaves are again a feature, for the premature drying effect at the top of the leaves is minimized in that the upper part of the leaves tending to dry first rotate into the draining and are rewetted. This action, combined with the uniform cake and equi-resistance preserved by the muddied wash, enables the drying effect of the compressed air to function better than is the practice with stationary filter leaves.

Discharging the cake from the Vallez filter is undoubtedly the spectacular feature of the operation of this filter. In stationary leaf filters dry discharge by reverse compressed air generally means that the bulk of the cake falls at one instant and often with sufficient force to splash and spatter outside of the hopper. This means that cleanly conditions about the filters are hard to maintain. Only when sluicing is used in Sweetland filters is an approach made to the cleanly discharge obtainable from the Vallez filter. The secret of this is the discharge without opening the filter. The cake is dislodged by reverse compressed air, assisted by compressed air streams from the sluicing nozzles for dry discharge or water from the nozzles for wet discharge. The cake falls to the bottom of the machine and fills the hopper of the screw conveyor. This scrolls the cake to the center of the machine from which it falls through the large opening into another outside conveyor or refuse pipe. The side arms on the filtering element now act as scrapers pushing the cake into the conveyor, so that it is continuously kept full until all the cake is removed.

It is usual and good practice to open the inspection doors and through them note the progress of the discharge. This has the added merit of letting the operator inspect the cake prior to starting the discharge, so that he can be sure all cloths are filtering uniformly and that the cake tester is properly indicating the cake thickness.

The operation of the Vallez filter is just the same in principle to that of the Kelly and Sweetland filters but, whereas there was some modification in handling the Sweetland over that in working the Kelly, the Vallez offers even more variation. The rotating leaves is the basis of the difference, but the effect of the rotation surely reduces the skill required of the operator and makes uniform results easier to obtain. We must appreciate Vallez's vision in perfecting the mechanics required to make a workmanlike job of making all the leaves rotatable so that

the advantages of rotary leaves could be demonstrated. Successes like this mark true progress in the art of filtration and are forceful examples of the value of relatively simple ideas. If Vallez was not the pioneer in rotary leaf filters he is the sponsor for their successful operation in the beet sugar industry and deserves immense credit for this monument to his ability.

Layout.—The layout for this filter does not vary greatly from the layout for Sweetland filters as regards piping of supply lines and filtrate discharge, save that connections can be made to the bottom half, which in the Vallez filter is not movable. The cake discharge being from the manhole opening allows the machine to be set up with only a small clearance between floor and bottom of filter.

The feature of the layout is the drive for rotating the leaves during the operation of the filter. This can be a belt drive from a line shaft or through worm and gear reduction direct from motor.

Sufficient headroom must be provided in order to lift the top half off by block and fall or crane carried on a mono-rail. This half has to be removed when the leaves require recovering or renewal.

Advantages.—The rotating leaves decrease tapering cake formation and more uniform cakes are presented for better washing and discharging.

Holding the sluicing nozzles in fixed position and rotating the leaves against the sluicing streams is the most positive sluicing arrangement in any filter yet devised.

Scrolling the cake to a central opening makes dry discharge a cleaner operation than is obtained with any other pressure leaf filter.

Discharging the cake, either by wet or dry methods, without opening the press is an advantage, not only in time and labor saving but in maintaining positive leakless gaskets.

The locked filter is, in effect, a closed container so that insulating against heat losses is practical and a true advantage of the Vallez filter.

Drawbacks.—The mechanical complications involved to gain even cake formation, the primary function of the Vallez filter, are drawbacks inherent in the machine.

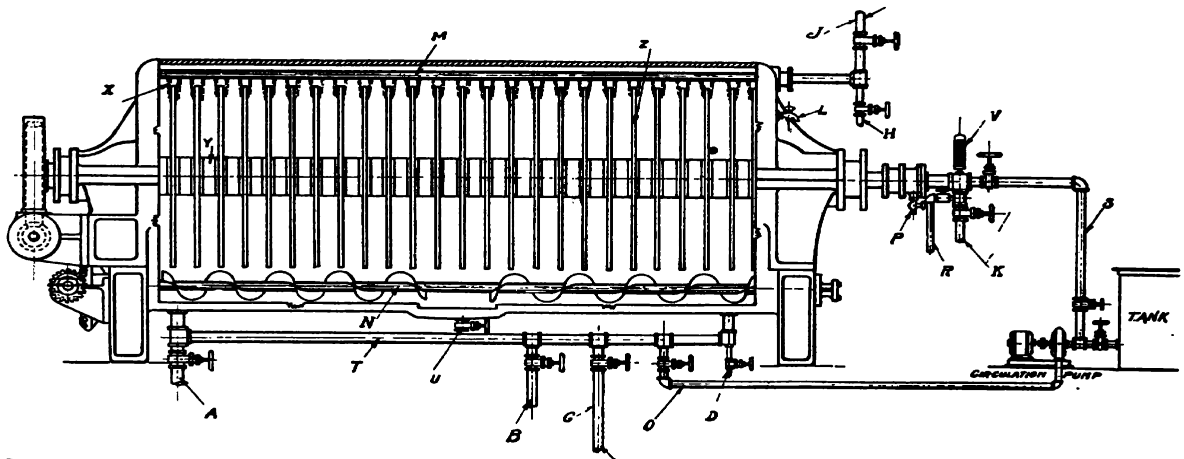
Inaccessibility to the filter medium for renewals, inspection or repairs is fundamentally a weakness in design appearing as a drawback of real importance when handling difficult filtering materials.

There are too many bolts used in the design of this machine for chemical liquors corrosive to the threads and heads. This is especially true in respect to those bolts used in the rims of the filter leaves.

Stringing the leaves on one central filtrate shaft requires good workmanship in the assembly of the leaves, for any defect cannot be isolated but requires removing the entire filtering element.

The overhead crane, or trolley, requires space and structural supports that add to the complications of this machine.

Applications.—For handling calcium carbonate cakes in beet sugar plants the Vallez filter has established a pronounced success. The character of work required here typifies the class of work to which the Vallez filter is especially applicable. Any liquor which can be modified



Courtesy Vallez Rotary Filters

FIG. 69.—Layout Vallez Filter.

A—Outlet pipe for excess or water
B—Inlet pipe for water
G—Inlet pipe for solution
D—Steam valve
P—Test cock
V—Thermometer
H-J—Air and water
L—Air cock
Z—Filtering frames

T—Header
S—Return pipe
K—Outlet for filtered solution
R—Outlet for wash water
M—Header for sprays
N—Screw Conveyor
X—Spray
Y—Shaft
U—Sewer valve

to parallel carbonation liquors falls in this class. As a sluicing filter it has application as a clarifying filter wherever the solids can be discharged wet.

Summary.—The Vallez filter is the latest of pressure leaf filters and represents a development evolved from actual plant operation with older pressure leaf filters that proved weak in practice. It is a striking example of the power of constructive criticism in developing a new filter as well as a challenge to manufacturers who fail to maintain a constant research in order to better their machines.

The cyclic operation of this and all pressure leaf filters is in contrast with the continuous operation of automatic filters. These machines are cyclic in respect to the work done by each filter compartment but, being free from actual valve manipulation by the operator, automatic machines are advances in the art of filtration.

Chapter VI.

Rotary Vacuum Filters.

In all our preceding discussions, each filter has been intermittent in its operation, requiring an operator to change from filtering to washing, to discharging, etc. Automatic continuous filters, therefore, are a step forward since they require no labor in the operation of valves switching from cake building to washing or drying or discharging. The rotary filter is continuously filtering and, at the same time, continuously washing and discharging, there being no interruption in changing from one operation to another.

Rotary suction filters are not the latest development in the modern filters, for even before George Moore developed his suction leaf and then his rotary filter, rotary continuous filters were working on free-filtering salts. These machines were, however, confined to only the very free-est filtering material and those filters starting with Moore's rotary; the Oliver; the Portland; and the American continuous, are capable of handling a greater range of material.

The modern rotary continuous filter is designed with the idea of subjecting ⅜ of the filter area to work of filtration, ½ the filter area to washing and drying, and the balance—⅙—to discharging. These fractions are of course variable, but in a given rotative speed the time allotted for filtration is seen to be less than half the time required for the total cycle. In consequence, materials capable of building up a cake ¼ in., or greater, in thickness in from 1 to 4 minutes' actual filtration, represent materials on which these filters are practical. Where a material will build up a cake greater than ¼ in. thick, the rotative speed can be varied so that the time of filtration is confined within the limits of the high filtering rate of the material. Here is one of the decided advantages of this type of filter too often overlooked.

The following chapters will deal with the *single compartment* drum filter; the Moore filter and its descendant, the Zenith filter; the Oliver and the Portland; and American Continuous Filter.

The *single compartment* machine is the old original type and the others,—the *multiple compartment* filters,—are modern filters based on one principle and differing each from each in mechanics only.

The single compartment machine is characterized by the absence of any control valve and by the fact that the scraper never cleans all of the cake from the filter surface. The Moore, and Zenith, resemble the more familiar Oliver and Portland drum type filter, but are made with the

scraper *not* resting on the wire-winding on the drum. The Oliver and Portland filters are equivalent machines, so that each is characterized by the scraper *resting on* the wire-winding of the drum. The American continuous is a sectionated leaf filter, the leaves being mounted at right angles to a central shaft so that filtration takes place on areas distributed transversely to the axis rather than on the periphery of a drum.

It is understood, then, that the following discussions on these respective filters are sub-sections of the general subject—Rotary Vacuum Filters.

Chapter VI.

Section I—The Oliver Filter.

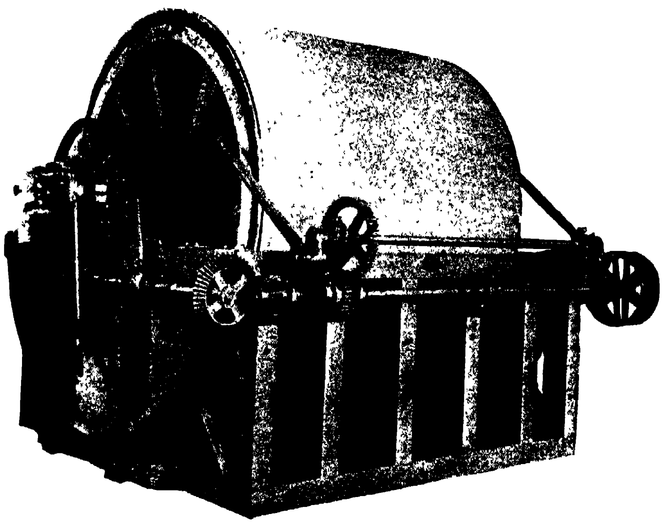
The first continuous drum filter had been long in operation in the alkali industry (handling sodium bicarbonate crystals), even before George Moore developed his design, which was to prove first of the modern filters. Modern filter development may well be dated from Moore, because he first hit upon a scheme truly better than the time-worn plate and frame press.

The early drum filter was too limited in application to be a significant step forward in filter progress, but its difference from earlier presses made it interesting, nevertheless. It was a single compartment drum machine, with a perforated periphery covered with filter cloth. The ends of the drum were made water and air tight, so that a pipe, extending through stuffing boxes in the hollow trunnions of the drum, and leading down to the low point of the drum, was used as the exhaust pipe for air and filtrate. In operation some cake had to remain on the cloth after the drum passed the scraper, or else the suction would violently pull air through until that part was again immersed. Such a filter is limited to only the freest filtering material, for the cloth must be completely cleaned where the filter handled anything below crystalline solids. In order to overcome this air short circuit the cleaned part of the filter must be cut off from the vacuum supply. Here, then, is the reason for sectionating the filter area.

Origin.—George Moore, whose vacuum leaf filter marked the advent of the modern filter methods, early realized the limits of intermittent filtration. His first effort to effect a continuous machine was the design of a master mechanism which was a timing device to automatically operate his leaf filter. It was designed to lower the leaves into the tank; throw on the vacuum; after a given length of filtering time, to lift the leaves from the tank; to throw in another cable to bring the leaves over the wash water tank; to lower them, etc., etc., so as to complete the entire cycle. Such a mechanism was at once intricate and too inflexible to be a commercial success. Moore appreciated this sooner than some of his colleagues. He then borrowed from his technical training, and, analyzing the shortcomings of the rotary single compartment filter for fine crystals, set out to sectionate the drum into multiple compartments. Here was his start of a continuous filter embodying the advantages of the free cake formation, which was fundamental in his leaf filter. Moore, however, lost heart in filtration when his company passed into the control of promoters, rather than engineers, so that his filter development was sidetracked in favor of exacting royalties.

Before the Moore Filter Company passed out of existence, it licensed a subsidiary company, the International Filtration Company, later reorganized as the Industrial Filtration Corporation, under the Moore Process patents, to manufacture and sell filters to the industrial field. The rotary filter was redesigned and put out as the Zenith filter.

E. L. Oliver was a mining engineer, operating a cyanide mill contemporary with Moore. Oliver appreciated the possibilities of the rotary type machine, and used his ingenuity to effect a simple workable machine. His control valve and the spiral winding of the drum, to hold down the



Courtesy Oliver Continuous Filter Company

FIG. 70.—Oliver Acid-Proof Filter—Continuous Drum Filter.

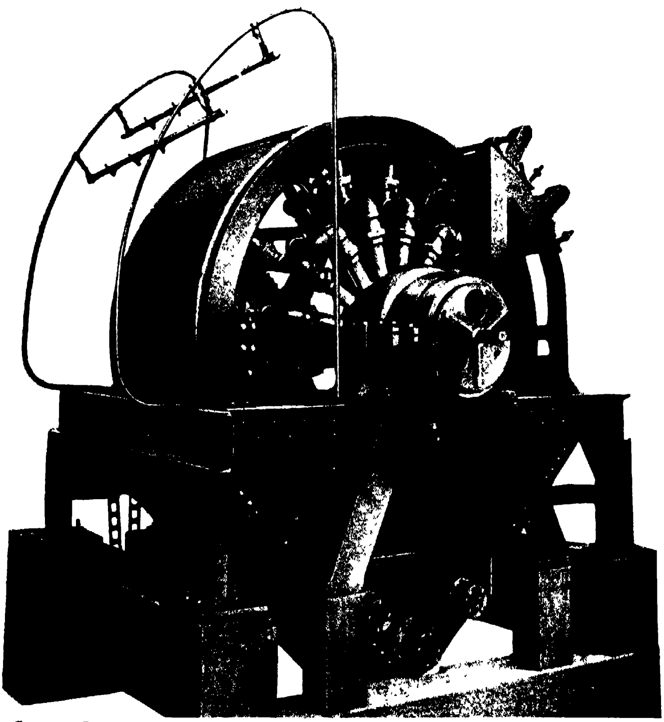
For many materials, contact with iron causes contamination requiring a wood and bronze construction. This type of filter can be ruggedly built to meet such conditions.

cloth and to prevent the scraper cutting the cloth, spelled success for his Oliver filter.

Oliver had proven out his filter when a group of engineers at the Portland Mill of another gold cyanidation plant were attracted by Oliver's results. They endeavored to effect a contract to build their own filters under a license arrangement. The two parties could not agree, and the Portland engineers started out for themselves. They developed a better compartment sealing than Oliver had, but needed Oliver's wire winding. The Butters-Moore patent fight had been disastrous to both winning and losing company, so that the potential fight between Oliver and the Portland Mill was obviated by an interchange of licenses under their respective

patents. The success of the Oliver and Portland filters demonstrates the wisdom of this arrangement.

For purposes of our discussion, the Oliver Filter is used to typify this group. Specific mention is made of one of the other filters in case of a decided difference from the Oliver. The Oliver is entitled to the position



Courtesy Industrial Filtration Corporation

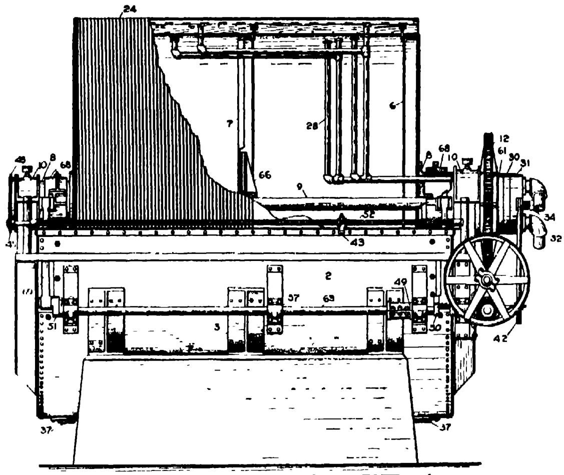
FIG. 71.—Zenith Rotary Continuous Filter.

Maximum strength of materials of construction, pipe and port areas, etc., is the dominant feature in this design. With free filtering material the submergence of the drum can be decreased so that the shaft and bearings are above the liquor level and free from contamination.

of leader, not only by the greater number of filters built and operating, but by reason of the greater service rendered in introducing the machine into many diverse fields of application.

Design.—In the Oliver filter the filter area is divided into compartments, each of which is independent and separate from every other. The mechanics employed are those patented and held by the Colorado Iron

Works,—the feature of their Portland Filter. In effect, each compartment is a panel, the filter cloth being secured in the longitudinal division strips by driving a stout rod, or sash cord, into machined grooves after the filter



Courtesy Oliver Continuous Filter Company

FIG. 72.—Details of Oliver Continuous Filter—Side View.

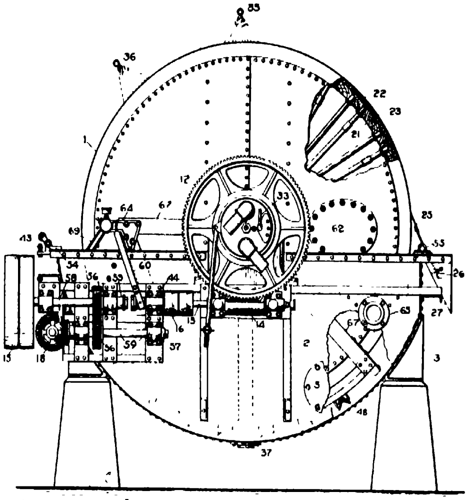
List of Parts:

1—Filter drum
2—Steel filter tank
3—Tank supports
5—Tank manhole
6—Channel steel drum rims
7—Channel steel drum arms
8—Hollow cast iron trunnion
9—Steel drum shaft
10—Main bearings
12—Worm drive gear
13—Worm shaft
14—Oilwell for worm
15—Drive pulleys
16—Wiring pulleys
18—Bevel gears
21—Wood staves for drum
22—Division strips
23—Filter medium
24—Wire winding
25—Steel scraper
26—Scraper adjuster
27—Apron
28—Vacuum and air pipes
30—Removable valve seat
31—Automatic valve
32—Vacuum connections
33—Air connection
34—Valve stem

The filter cloth is bound to the drum by spiral winding, which also prevents bulging of the cloth with reverse compressed air and serves to protect the cloth from the scraper. Each compartment has two filtrate-collecting branch pipes leading to a common pipe which feeds through the rotating hub to the control valve.

cloth has been pushed into the grooves. The compartment strips are tight against the drum, and the filter cloth is tight in the grooves on top of the strips, so that leakage is positively eliminated. The side edges of each compartment are sealed by wiring the cloth to the drum.

Each compartment has its own outlet pipe. In the Oliver, two outlets leave the compartment, but join together in one pipe, passing through the hub of the machine. One of these branches is located on the leading side,



Courtesy Oliver Continuous Filter Company

FIG. 73.—Details of Oliver Continuous Filter—End View.

List of Parts:

35—Wash water sprays
36—Wash solution sprays
37—Drain flange
42—Valve adjuster
43—Wire spacing nut
44—Worm shaft bearings
45—Wiring sprockets
48—Oscillator rakes
49—Shaft coupling
50—Agitator crank
51—Agitator crank
52—Wiring feed screw
53—Jaw clutch
54—Wiring screw bearings
55—Scraper bearings
56—Spur gear
57—Oscillator shaft bearings
58—Pulley shaft
59—Intermediate shaft
60—Clutch shifter
61—Valve pipe plate
62—Drum manhole
63—Oscillator shaft
64—Connecting rod bracket
65—Overflow weir
66—Center spider
69—Connecting rod

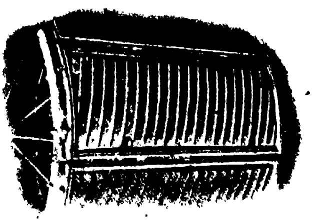
The ends of the drum are closed to reduce the amount of unfiltered liquor and a manhole is provided for assembly or repair to filtrate pipes. Wash water is sprayed upon the ascending cake from atomizing nozzles located above the drum. An oscillating agitator maintains uniformity of liquor within the container.

and the other on the lagging side of the compartment, so as to facilitate draining, irrespective of the angular position of the compartment.

The main outlet pipe from each compartment passes through the hub of the machine with the outlets of adjacent compartments side by side.

These are arranged in a circle, so that they register with the annular port in the stationary member of the valve.

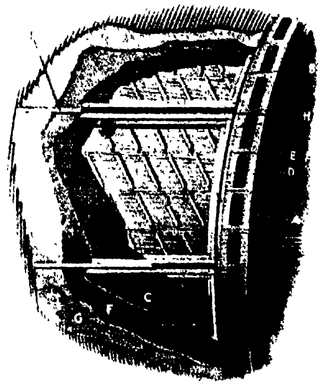
Inasmuch as the sliding surfaces of the movable and stationary parts of the valve are ground surfaces, and consequently wearing surfaces, it is preferable to have these parts readily accessible and easily removed if in time they have to be replaced. In the Oliver filter this is taken care of by bolting to the rotating hub, or trunnion, a wearing plate in which holes are drilled registering with the outlet holes in the hub. This plate is now



Courtesy Colorado Iron Works Co.

FIG. 74.—Portland Filter—Drainage Compartment Uncovered.

Each compartment of a continuous filter is in effect an independent filter. Drainage of filtrate and means of sealing the filter cloth around the compartment are vital parts of the design of such filters.



Courtesy Colorado Iron Works Co.

FIG. 75.—Portland Filter—Compartments in Section.

Over a drainage member of wood or cast iron, a wire screen "C" is laid. Over the screen some porous fabric "F," as burlap, is often used to cushion the filter cloth "G."

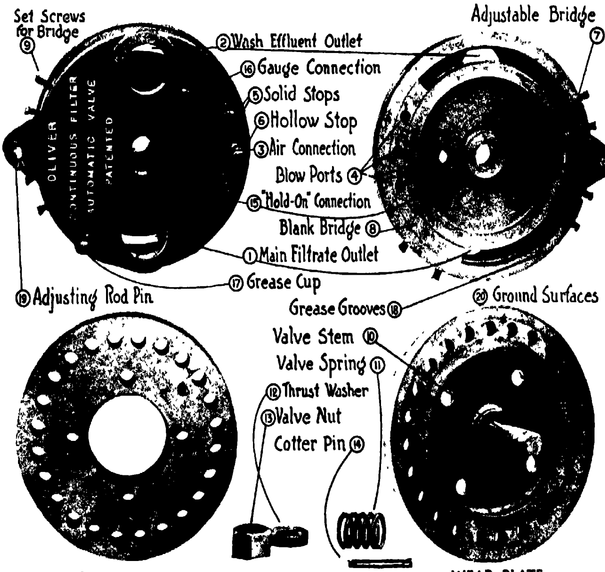
the wearing surface of the filter, and saves deterioration of the filter proper. Before assembly to the filter this plate is ground into positive contact with the stationary member.

The keynote of the valve is the stationary or outer cover of the valve. This is in reality a universal valve, controlling vacuum or compressed air supply to the individual valves. Its prime feature is the annular port and the blanks or bridges in this port. A hole in the center centralizes it on the shaft extending from the wear plate. The annular groove or port registers with the outlet holes of the wear plate, so that each compartment is in communication with the vacuum or compressed air, according to its position. The dividing member between vacuum and compressed air is a metal blank in this annular groove.

The lug or ear cast on the edge of the stationary member carries a pin

to which an adjustable rod is attached. This rod is bolted to the frame of the filter, or to the floor, and serves to hold the valve stationary. Adjustment is obtained by threading the nut of the rod to the desired position.

Consider the valve assembled so that the exterior of the stationary member, shown in the upper left hand corner of Fig. 76, is facing



Courtesy Oliver Continuous Filter Company

FIG. 76.—Oliver Continuous Filter—Automatic Valve.

The upper right-hand cut shows the under side of the piece shown in the upper left corner. The valve is assembled by bolting the removable wear plate and valve seat to the end of the filter, each hole registering with a filtrate pipe from a compartment. The stationary member is centered by the valve stem and held against the wearing plate by the valve spring and nut. Rotation of this member is prevented by the adjusting rod pin.

out. The large hole at the bottom is the filtrate connection. This, it will be seen, opens to the annular port and is designed to carry off all filtrate obtained from the time when the compartment submerges until it emerges from the liquor.

The reason that this outlet does not take any filtrate beyond that point is that the adjustable bridge closes the annular port. Note that the under side of the stationary head, as shown in the right hand corner of the cut, is not a sectional view, but the view seen when the right corner picture is

turned over on its right hand edge. This means that the bridge No. 7 is located to the left of the filtrate connection, as seen in the right hand corner picture. This bridge serves as a separator for the filtrate and for the wash effluent.

The weak filtrate, or wash effluent, is taken off by the large hole at the top. All filtrate obtained from the compartment after emerging, until arrival at the discharging position, is carried away from this opening. The bridge, as well as the other blanks, is ground in when the valve proper is ground so that the bridge is an effective seal. Note that the bridge is movable in the annular slot so that the arc in which the filtrate connection acts may be increased to any desired point above that of emergence. Also, the bridge is removable so that the wash effluent connection may be plugged up and all filtrate drained from the lower outlet. This flexibility of the outlets is a feature that often makes the difference between success and failure.

The entire mechanical arrangement of the Oliver filter is principally for the one function of complete discharge of the cake. This part of the valve is, therefore, the important part of the valve construction. In brief, it is the changing the compartment from vacuum suction to compressed air blow. If the bridge between the filtrate outlets is an effective seal the same construction would seem rational for the dividing member between vacuum and compressed air. The only difference, however, is that this bridge is made longer. The actual blow or reversed current is admitted through either one or all of the blow ports.

The compressed air connection is shown as No. 3 in the cut. A cored opening communicates with the three blow ports and those desired closed off are plugged with solid screw nuts, No. 5 in Fig. 76, easily inserted from the outside. The hollow stop leaves the blow part open but closes the internal cored passage from leakage to the outside.

After the compressed blow and discharge of the cake, the cleaned cloth must be idle until fully submerged. Another blank beyond the blow ports takes care of this.

Ground joints should be lubricated and, in the Oliver, valve grease cups are arranged for the outer and inner rims of the annular port.

Reverse compressed air is not alone an effective means of discharging the cake. First, the compartment is in a position so that gravity cannot assist; and second, the ballooning effect would tend to open up the cloth secured in the compartment division strips, hence a scraper or doctor is also required.

If a scraper is used like that prevailing in the single compartment old type filters its function should not be the same, for in the Oliver it is more of a deflector than a cutting plate; but it does become a true scraper if the cloth balloons out against it. To prevent this bellying out of the cloth, E. L. Oliver patented the idea of spirally winding the surface of the drum with piano wire. The wire is spaced as close as ¾ in. centers, but can be wound in wider centers if the product being handled is easily discharged. Note that with spiral winding the scraper can be set up against the wire without endangering the cloth and, at the same time,

wear on the plate is uniform across the entire edge without any grooves becoming notched in it.

Since gravity does not assist the reverse air discharging the cake, the angle at which the scraper is set must be greater than the angle of rest of the discharged material. Also, the plane of the scraper should be a tangent to the drum at the point of discharge. These two factors preclude the scraper being set too high above the horizontal axis and in most machines it is located just above the center line of the machine.

If, in leaf filters, the uniform resistance of the cake made possible displacement washing of the cake, we may well expect that the cake formed on Oliver filters offers a similar opportunity, if an approach can be obtained to the submergence of the leaf filter under the wash water. In addition to applying the water as a complete coating it is necessary not to disturb the cake formation by too forcibly applying the water, or by applying more water than can be sucked through the cake, for then the excess runs down the cake and erodes away the surface of the deposited solids and tends to weaken the strong liquor in the container. This means, then, that the water must be applied as a fine spray or dew directed against the cake. Spray nozzles are, therefore, located on the ascending side of the drum above the container and the amount of water fed to the cake regulated by an ordinary valve.

The time for washing is necessarily limited by the fact that the water application must be a maximum at the zenith of the travel. This would seem to be a limitation but, so long as the wash percolation is greater than the voids of the cake, the wash should approximate true displacement. A wide variation from this amount of wash water is an indication of either too high a vacuum pressure during filtration or else an improper distribution of the wash water. The secret of the excellent record of these filters as washing machines is that only relatively thin cakes are built up and their form preserved until washing is completed.

In continuous filters agitation in the filter tank to prevent settling of the coarser material is a necessary part of the design. Rotating paddles at the bottom of the tank and air lift connections taking the settlings and circulating them to the top of the liquor are not as effective as the oscillating arm agitator now adopted as standard. This device consists of a number of angle irons of equal legs attached to circular arms conforming to the curvature of the container. Side arms attached to the curved member terminate in cradles which hang on the bearing or shaft of the filter. A crank arm on a rotating shaft located behind the filter rocks the agitator back and forth so that the liquor is in constant motion.

Operation.—Being a continuous filter, the operation consists of once setting the valves, liquor level in container, the revolutions per hour of drum, position of the stationary head of the valve, washing sprays, and discharge scraper. In consequence, knowing how to start up the filter is knowing how to operate it at any time.

Mechanical lubrication should receive the first attention. This means oiling of bearings of shafts and of filter and turning down on grease cups,

especially those on filter valve. If a pump feeds the filter this should be oiled and stuffing boxes taken up liquid tight, but not too heavily.

The rotative speed being decided in advance, the driving belt should be located on the center of a cone step pulley and the filter rotated. Wherever the filter is equipped with an agitator attention should be given to clearing the container of bolts or other extraneous material which may have fallen into and could cause trouble by jamming the agitators.

Before starting filtration the drum should make several rotations with the container filled with the slurry. If wooden lagging is used on the drum, or wood construction used throughout, it may be necessary to first swell all the wood by filling container with hot water.

On starting the filtration the full displacement of the vacuum pump should be taken from the filtrate receiver only. After ½ revolution the dry vacuum connection from the wash filtrate receiver can be cracked and after a full revolution opened up full. This procedure lessens the duty of the dry vacuum pump which would otherwise pull too much air through the exposed filter cloth above the liquor.

As soon as filtrate enters the receivers the exhausting pumps should be started. These pumps, especially if they are centrifugals of the usual type, should be piped up with a check valve in the discharge line and an equalizing line back to the receiver. This equalizer is simply a gas relief which insures any liquor in the receiver falling into the pump. The equalizer can be located on the suction line, or on the discharge line, although it is preferable to put it on the suction. The pumps must, of course, be located on a level below the bottom of the receiving tanks.

The dry vacuum line is connected to the top of the receiving tanks; the filtrate inlet is connected to a side opening and the filtrate outlet at the bottom. If the pumps fail to exhaust the filtrate as fast as it enters the receiving tanks, there is danger that the liquid will be drawn over into the dry vacuum pump. This machine is designed with very small clearances and liquid is not expected to be pumped by it, consequently, provision must be made to prevent the liquid rising into the vacuum lines.

In the Oliver tanks a float is provided which closes the vacuum line when the liquor rises to a given point in the tank. This seals the dry vacuum lines from liquid and saves the pump from possible injury.

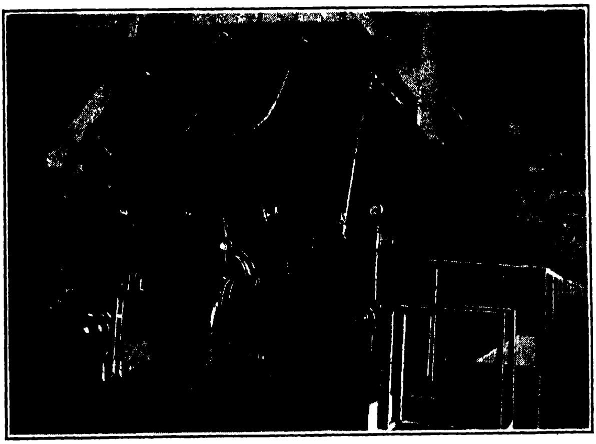
Unless the material being handled cracks badly when subjected to the drying action, there should be a slightly higher vacuum on the compartment as it leaves the liquor than on the compartment during filtration. This requires, then, that a vacuum gauge be located on each of the two receiving tanks. Having a greater filtering force after the cake is built up, with its consequent resistance, means that more wash water can be pulled through the cake and a better dewatering effect obtained than if the filtering force is held constant throughout the operation.

The actual differential in vacuum is a variable depending upon the material being handled but, on the average, it will be found that a filtering pressure of 15 in. vacuum and a washing or dewatering pressure of 24 in. vacuum will give admirable results.

With those materials that crack quickly this differential is impracticable.

It is far better to reverse the pressures, even lowering the dewatering pressure just enough to insure the cake adhering to the drum.

Washing is, in theory, displacement washing, so that effort is made to envelop the cake with a film of water as though the cake were submerged. At the same time, the water must not disturb or erode the cake, as otherwise the uniform resistance is not maintained. Therefore, the spray nozzles must be set close enough for the spray to land on the cake without disrupting it. The volume of spray must be within that which the vacuum pulls through the cake, or otherwise the excess will drain down the cake,



Courtesy Oliver Continuous Filter Company

FIG. 77.—Battery of Oliver Continuous Filters—Washing.

In order to prevent driftage of the atomized wash water side plates are provided, the function of which is to prevent draughts reaching the spray and to localize the spray. On large machines it is practical to distribute six sprays through the washing arc to get a long washing cycle.

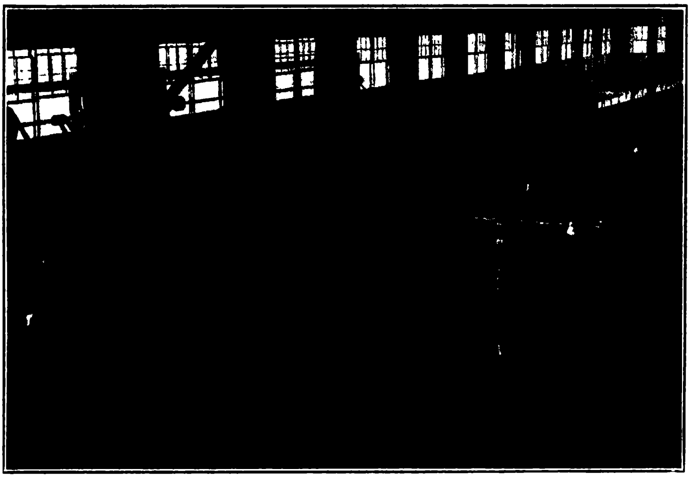
eroding it and contaminating the strong liquor in the tank. Driftage of spray should be prevented by curtaining against windage or prevailing drafts. Driftage is a nuisance around the machine and represents water that should have been used to wash the soluble from the cake.

Spray nozzles are made of varying designs, but in all a fairly high water pressure is required. If the water pressure is a variable the quality of the spray is not constant and in some plants it is advisable to independently pump the water required for washing. Dirt, scale from piping, rust, etc., should be kept from the nozzles as such matter often partly clogs the nozzle opening and prevents good atomization. If atomizers are continually plugging up it is well to independently filter this water.

Dewatering on Oliver filters is analogous to that of leaf filters and is economic only till crack or pit hole formation makes the air short circuit

too great. Rather than pull needless air through such cracks, it is good practice to blank off the drying port and let the filter run idle till the point of discharge.

Discharging requires that the cake be lifted from the cloth and that the scraper act as a deflector. This means that the reverse compressed air forcibly lift and disengage the cake from the cloth. Since the cloth is spirally wound with wire the reverse pressure can be much higher than practical with leaf filters. As it takes a fraction of a minute for the compartment to pass under the scraper, one blow of compressed air will issue



Courtesy Oliver Continuous Filter Company

Fig. 78.—Oliver Filters—Washing.

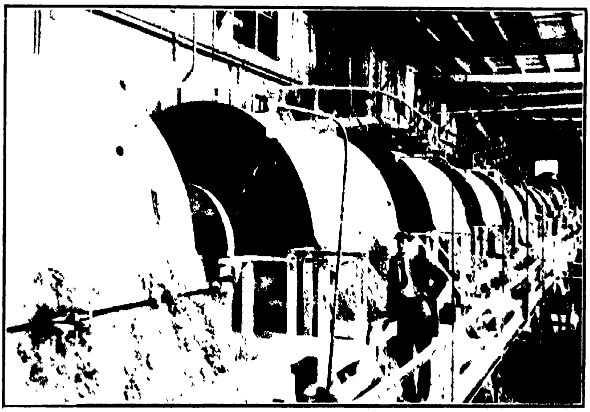
The wash water must be played on the surface of the cake completely and mildly—as a dew. Atomizing nozzles dividing the water into fine particles best accomplish this result.

through the cloth before the entire compartment is discharged, consequently, a second blow facilitates discharging the remaining cake. This successive back blowing is also economical in the use of compressed air making the total requirement for even a large filter that of a comparatively small compressor. The third blow hole in the blow back port is often advantageously used to further clean the cloth after the compartment has entirely passed the scraper.

There is an interval between the discharge of the cake and the new cycle of filtration and care should be taken that the blank in the annular port is long enough to allow the entire compartment to be completely submerged before filtration starts. If only part of the compartment is under the liquor the vacuum pump will pull air through the exposed cloth

and the vacuum pressure falls by reason of the added and unnecessary duty on the pump.

If the material being handled varies in its filtering characteristics, or if a new filter is being put into operation, some adjustment is very likely needed in setting the positions of the blanks between the different ports. The blank between filtrate and wash effluent should be fixed so that only strong filtrate drains into it. If a resistant cake is formed this blank can be moved up to a higher position than when a more open cake is deposited. If the cake cracks too much the blank in front of the blow ports should be carried back, although never short of the zenith of the



Courtesy Oliver Continuous Filter Company

FIG. 79.—Oliver Filters Discharging.

The scraper rests against the wire winding and reverse compressed air lifts the cake from the cloth so that the scraper acts as a deflector. The angle of the scraper must be steep enough to insure the cake falling from it.

travel of the drum. Also, with some quickly classifying materials the dead blank prior to filtration can well be extended so that the compartment starts filtering at the lowest point of travel.

There are other points in the operation of Oliver filters such as housing over the drum when hot or volatile liquors are handled, installing condensers on dry vacuum line to save duty on vacuum pump, etc., but after once fixing these conditions the machine operates automatically. Periodic inspection is required only to insure mechanical operation, liquid is flowing to the filter tank, that the clarity is maintained and discharging is complete.

Layout.—The layout for the Oliver filter closely parallels the layout for the vacuum leaf filter, at least in its accessory equipment. The difference in accessory units lies in the fact that there is a continuous load rather

than periodic peaks and slack intervals so that the individual units can be smaller for the same daily or hourly production.

The layout varies with the work being done. There is the simple arrangement for straight dewatering of cold liquors, a moisture trap or condenser for dewatering hot liquors, separate receivers for washing the cake from cold liquors with a moisture trap when handling hot material. Each case is further modified by whether dry or wet vacuum system is employed.

The filter must be set up so as to have a free drain for unfiltered liquor at end of run and for washing down of machine. There should be sufficient headroom provided to lift out the drum should it need overhauling at any time. The location is preferable where sufficient room is provided for the accessories close to the filter, as observation control on these should be convenient when regulating filter.

The material to be filtered must flow freely to the machine with a minimum number of turns, all elbows eliminated and substituted with plugged tees or crosses. A regulating valve, preferably of delicate adjustment, should be handy to filter so that level of liquor is easily maintained.

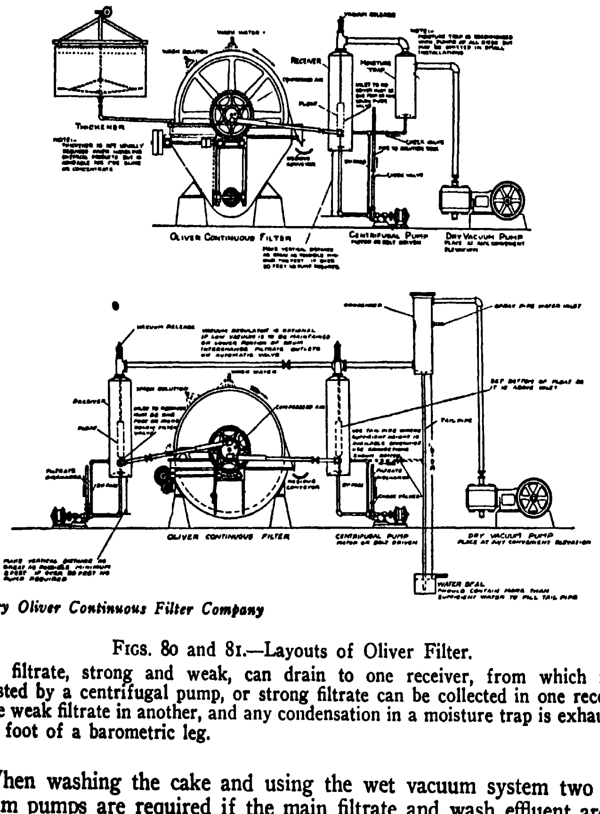
Agitation is provided in the mechanism of the machine itself and the rocking plow type is generally the most efficient. The liquor level can be maintained at any desired height but the control valve must be adjusted, if the level is low, so that the compartment re-entering the liquor is fully submerged before starting filtration.

For work of dewatering only, when using the dry vacuum system, the layout comprises one vacuum receiving tank, one dry vacuum pump and one exhaust for the filtrate. The latter can be a barometric leg, when the elevation of the vacuum receiving tank is at least 30 feet above the point of discharge of the filtrate, or a centrifugal pump can be used, provided the vacuum receiving tank is placed above the pump so that there is head of 1.2 times the vacuum pressure in excess of 22 in. on the pump. This insures gravity flow to the pump and enables a centrifugal pump to exhaust the filtrate. If a hot liquor is handled, a moisture trap or other means of condensing the steam vapor is placed in the vacuum line so as to prevent any condensate precipitating in the dry vacuum pump and straining or breaking any of its parts.

If the wet vacuum system is used for dewatering only, the filtrate line is piped directly to the wet vacuum pump and the discharge from it is both filtrate and air. The Nash Hytor Pump is especially advantageous for this work, but if the filtrate is to be delivered to a level higher than the pump an auxiliary lifting pump of ordinary centrifugal design is required. If cold filtrate, or, where permissible, cold water, is added to the circulating liquor in the Nash Hytor all steam vapor is condensed even when handling hot liquors. This pump, however, will handle the product even if the vapor is not condensed.

When handling liquors, cake of which must be washed, and it is desired to separate the weak wash filtrate from the strong filtrate, two vacuum receivers and two means of exhausting the liquor are required, when using the dry vacuum system. To one receiver is piped the filtrate obtained

from the main filter outlet on the valve and to the other the wash filtrate obtained from the other outlet which receives the wash only. Only one vacuum pump is necessary and otherwise the system is identical with dewatering cold liquors. When hot liquors are handled, a moisture trap is again necessary in the main dry vacuum line.



Courtesy Oliver Continuous Filter Company

Figs. 80 and 81.—Layouts of Oliver Filter.

All filtrate, strong and weak, can drain to one receiver, from which it is exhausted by a centrifugal pump, or strong filtrate can be collected in one receiver and the weak filtrate in another, and any condensation in a moisture trap is exhausted at the foot of a barometric leg.

When washing the cake and using the wet vacuum system two wet vacuum pumps are required if the main filtrate and wash effluent are to be separated.

If the exhaust pumps are oversize for the amount of filtrate obtained and are electrically connected or driven from the same motor as the vacuum pump, there is but small danger of liquor being drawn over into the vacuum pump when using the dry vacuum system. As a precaution, however, the vacuum receivers on Oliver filters are provided with automatic floats which cut off the vacuum inlet when the liquor rises above a given limit in the receivers and thus preclude all possibility of liquor entering the vacuum pump.

Advantages.—There are a number of advantages in the continuous filter that are prominent and obvious but probably most important is its fool-proof operation. Its efficiency is almost entirely free of the personal equation of the operator. The lowliest laborer can tighten up grease cups, oil the bearings of a slowly revolving filter and watch that the discharge hopper does not jam. He has nothing to do with the time of filtration, with the extent of the washing cycle, or manipulating valves in order to hold positive pressure during transferences of liquors. The universal valve does everything for him, automatically, so that his personal efficiency is a factor of practically zero importance. Constancy of product is of first importance and fool-proof operation is its best guarantee.

Labor saving, or as it is better called labor productivity, is practically a maximum with Oliver filters. Even a battery of machines requires less than one man's time so that a single operator can filter and discharge immense tonnages. The labor productivity is pretty close to a maximum for it is only when recovering the drum that any real labor is involved. This is required whenever the filter cloth is worn out or plugged up and depends upon the material being handled. It may be necessary to do this once a year or once every two weeks. Relatively, however, recovering the filter is less frequent than with any of the intermittent operating filters.

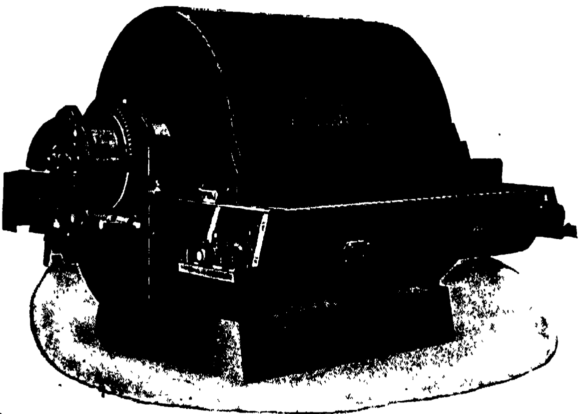
Washing the cake free of solubles in the Oliver filter is the most uniform of the filters so far discussed. The cake is maintained in its equiresistant condition more positively than in leaf type filters, and the time of washing is fixed by the arc of rotation set for wash filtrate. While it may not be possible to completely free the last trace of soluble, and varying quantities of water are required, depending upon the porosity of the cake, still, on the average, the washing efficiency stands highest in these filters.

Good discharge of the cake is vital to any filter and whenever it is complete for cycle after cycle it can be called an advantage in favor of that filter. This is the case in the Oliver, and more, the discharge is truly automatic. In leaf filters the operator must manipulate the valve for reverse compressed air—in the Oliver, the universal valve admits the reverse pressure without any one handling any valve. Being able to rest the scraper against the wire winding on the drum makes the work of the compressed air simply that of disengaging the cake from the cloth—it does not have to push it away from the leaf as in leaf filters. It is only when the thickness of the cakes is ¼ in., or less, that any trouble occurs in discharging and, as the large majority of rotary drum filters work on materials forming cakes at least ⅜ in. thick, it can be safely stated that discharge is positive at all times. There are instances where the cloth becomes clogged, but these cakes are examples of poor selection of filter cloth rather than faulty operation of the filter.

The above advantages can be considered obvious but in the principle of operation there lies a fundamental advantage of marked importance. The time of filtration is a variable depending on the amount of submergence and the rotative speed. With the submergence constant, the filtering period is lessened with an increase in the rotative speed and conversely. In consequence, there is a balance for each material whereby

maximum production is obtainable. When once set, the filter then operates within the economic part of the filtering curve. This facility makes an efficiency of operation theoretically, but not practically, possible with intermittent filters. This advantage is limited to those materials which will form cakes of sufficient thickness for discharge, but is an essence of the possibilities of this type of machine.

Observation of the work being done is a requirement in any filter. Convenient observation means superiority in any filter and surely this is the case with continuous drum filters. The exposed cake on the ascending



Courtesy Oliver Continuous Filter Company

FIG. 82.—Oliver Filter with Repulping Trough.

Whenever the required wash cannot be obtained in one machine so that it is necessary to mix the cake from one filter with weak liquor or water and treat the mixture on a subsequent filter, it is advantageous to repulp the cake as it falls from the scraper. A repulping trough is also required when a succeeding operation requires the material be again suspended in a liquor—as in paper mills manufacturing direct from wood pulp which is washed on continuous filters.

drum, the discharged cake, the cleaned cloth dropping down below the scraper, and the wash water application are squarely in view and the ease of observation is truly a marked advantage.

Drawbacks.—The greatest weakness in the operation of Oliver filters is in the dryness of cake discharged. Sucking air through the cake in order to displace the entrained moisture is comparable to the drying cycle in pressure leaf filters. Cake cracking opens up paths of short circuit and defeats real dewatering of the cake. In this respect plate and frame filters are a distinct advantage where a compression of the cake is obtainable.

Washing the cakes depends upon the porosity of the cake to a large measure. If the material being handled changes so that an increased resistance is built up the water sprayed upon the cake must be throttled or else the excess will drain back into the container. This condition is

impossible for good results and requires, therefore, a measure of operator's control that should not be necessary with a continuous machine. This same condition of faulty application of washing water can also arise from inadequate pressure on atomizers. This cannot be blamed on the operator or on the design of the machine save only that it is an essential that makes the machine less self-contained.

Applying the wash water upon the cake is by atomization, so as to approach dewing water on the surface of the cake. For many materials this means atomizing to a mist fine enough to be drifted by the draught from an open window. This is a misdirection of the water, giving the cake less water than is needed and wetting the surroundings. Side curtains prevent these draughts but also detract from that important factor of easy observation and are only a make-shift wherever used.

Adequate pressure must be maintained on the atomizers and scale, or rust, or other extraneous dirt often fouls the nozzles spoiling the spray. The dew-like spray becomes a sturdy stream or is stopped up completely, either of which is contrary to the design of the washing method.

Discharging the cake by the joint action of reversed compressed air and scraper is effective wherever the cake is coherent enough for the air to lift it from the filter cloth. Thin cakes are often lacking in this quality and, consequently, the filter must be rotated at a speed enabling a thick cake to form. In these cases the capacity suffers by the reduced speed and, in some cases, becomes too small to admit the application of these filters.

Where difficult discharging materials are encountered the reverse air is admitted at a higher pressure. It is good practice then to spirally wind the wire around the drum on closer centers. The area covered by the wire is, after a short time, dead filter area and hence the effective area on the drum is reduced. This becomes a drawback when comparing this filter with one using less or no wire winding.

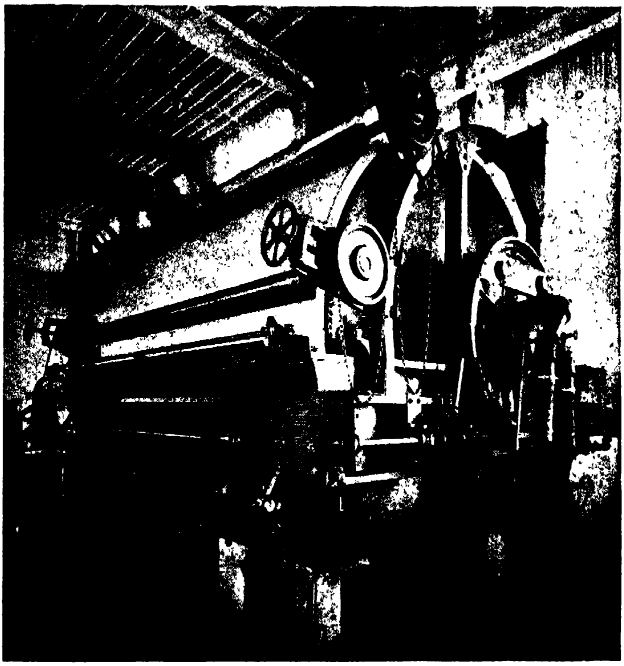
Positive clarity of filtrate is often impossible to obtain when the valve is supplied with two outlet ports only,—the usual design. The filter cloth will allow some solid to pass through it at the start of filtration and the first runnings cannot be separated from that obtained later and consequently clarity is a function of the filter cloth.

In industrial work, metal to metal surfaces are subjected to hard wear. Corrosion and erosion make the use of ground disk valves poor practice at best. The flat grinding disk valve in the Oliver filter is a drawback inherent in its design.

Depending on the filtration of air through the cake to displace the moisture in the cake is the conventional means of dewatering the cakes. The moisture content in the discharged cake, therefore, compares favorably with the pressure leaf filters but unfavorably with compressed cakes as obtained on plate and frame presses. Recovering the filter with new cloth requires removing the wire winding on the drum and the old filter cloth, then putting on the new cloth and rewinding the drum. In large filters this is a time taking job, and as such is a weakness in the design of the filter.

In the usual design, the maximum submergence is 35 per cent of the drum. This means that in the cycle only ⅓ of the time is given for filtration. For most materials this is sufficient, but for others this filter would be more efficient if the submergence were increased.

The area obtainable in the Oliver filter is that of the exterior of the drum. Filter area of 200 sq. ft., or more, requires drums 8 ft., or more,



Courtesy Oliver Continuous Filter Company

FIG. 83.—Oliver Filter—Large Dewatering Unit.

To aid the dewatering effect of filtering air through the exposed cake, it is practical, with a limited number of materials, to mount compressing rolls directly in contact with the cake. A slippage is required, hence the drive on these rolls which are often heated.

in diameter. Floor space and head room are required in excess of those filters wherein the filter area is in the form of filter leaves disposed as cross sections of the drum.

Applications.—The Oliver filter originated as an improved filter for cyanide slimes. It naturally spread to all mining mills and has been particularly successful on ore concentrates. The calcium saccharate in the beet sugar industry is largely handled on this continuous filter. Washing

of wood pulp has been demonstrated a big success in the paper industry. Free filtering solids of all descriptions, save those in highly corrosive, hot or supersatured liquors are handled by the Oliver. Difficult materials, when thickened as obtained from Dorr Thickeners, are handled with marked success with these machines.

Summary.—The tremendous success established by the Oliver filter is proof of the adaptability and practicability of vacuum continuous filters. Correction of some mechanical shortcomings in this filter has been made the basis for another vacuum filter, the American Continuous, but in this some of the advantages of the Oliver have been lost, as will be discussed in the following chapter.

Chapter VI.

Section II—American Continuous Filter.

When the United Filters Corporation was formed, it was the consolidation of the two leading pressure leaf filter companies: The Kelly Filter Press Company and the Sweetland Filter Press Company. This combination reduced competition and made possible the better distribution and sales of these filters. The competitor now was the Oliver Continuous Filter Company. The Oliver filter, being a continuous machine, had the grip on the industrial field where continuous filters were applicable. The American Continuous Filter is the continuous filter put out by the United Filters Corporation to compete with the rotary drum continuous filters on the ground of superior design.

The main theme underlying the design of the American Continuous Filter was to obtain large filter areas without necessitating large diameter drums so that a filter area of approximately 2000 square feet can be practically constructed and operated. The sectionated disk type of leaf, mounted transverse to the rotating shaft, was the simplest means of obtaining this desired end.

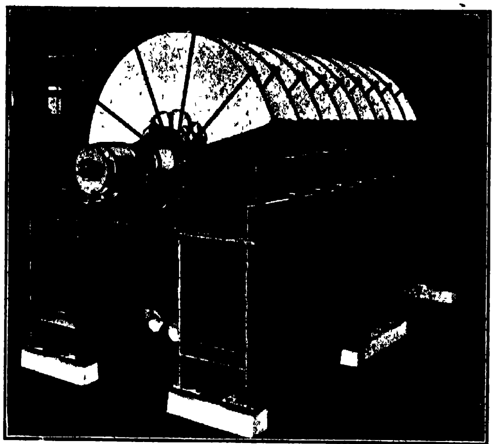
The advent of the American Continuous Filter on the market ended a long standing controversy on the relative values of vacuum filtration (which is always limited to the theoretical pressure of the barometer) and pressure filtration (which is limited only by the strength of the machine used). The American Continuous Filter became an indorsement of continuous vacuum filtration, and ended this controversy.

Its principle of operation does not vary from that of the original machine invented by Moore, years ago, or the principle used in rotary drum filters. The mechanical arrangement is the only difference, and this we shall take up in detail.

Design.—If the transverse leaf made up of pie-shaped, or sector sections, is the main theme in the design of this filter, there is a number of ingenious points that gives this machine the merits it has.

First, no wire winding of the cloth is required; second, a self-seating and self-grinding valve is used; and third, the separate pan construction as the container for the individual leaves is unique.

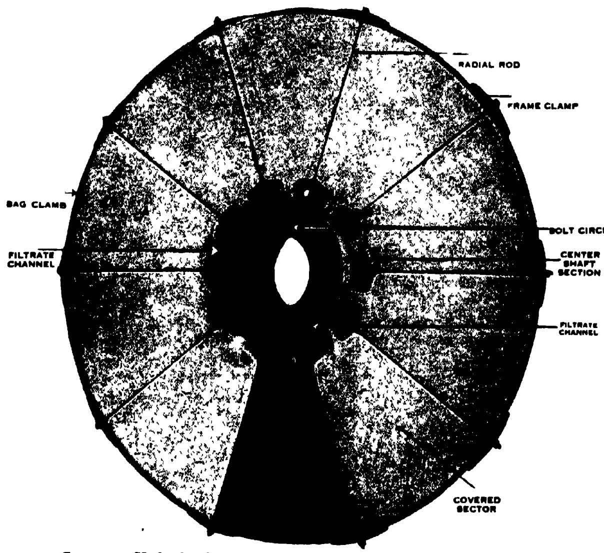
The leaves have for their basis of construction the same principle as used in the filter leaves of the Sweetland and Kelly filters. In other words, each individual section of the leaf is made up of a drainage member; an outlet nipple with a filter cloth bag enveloping the drainage member; and, secured to the outlet nipple, each filter disc is composed of eight or more individual sector sections and is assembled by dropping the outlet nipple



Courtesy United Filters Corporation

FIG. 84.—American Continuous Filter.

The filter area is divided into discs, each in turn divided into sectors, mounted on a rotatable shaft. The cake is discharged between adjacent leaves into a conveyor or hopper located beneath the filter.



Courtesy United Filters Corporation

FIG. 85.—Filter Disc or Leaf—American Continuous Filter.

Each sector in the leaf has an outlet pipe at its center which fits into openings on the filtrate channels. Each corresponding sector of every leaf functions simultaneously on this account. The leaves must be true planes and therefore the drainage member is best constructed of rigid material, as grooved wood, cast iron, etc. The leaves are assembled, each sector being inserted with its bag clamp, frame clamp and nuts threaded on the radial rods.

into its receiving port located on one of the main collecting conduits. The sector leaves are aligned by clamps secured at each radial aligning rod with a nut.

As many filter discs as are required are distributed along the machine, the individual sectors in each disc in the same arc of rotation feed into the same collecting conduit. Consequently, the one valve registers vacuum or compressed air to each sector in every disc.

By making up the filter cloth as a bag open at the outer curved end and a small hole through which the outlet nipple can slip through, hand sewing of the cloth to the sector shapes is eliminated. After slipping the bag over the drainage member the outer edges are lapped over and held in place by a curved U shape which fits over the periphery. This greatly reduces the labor required in putting on new filter cloth.

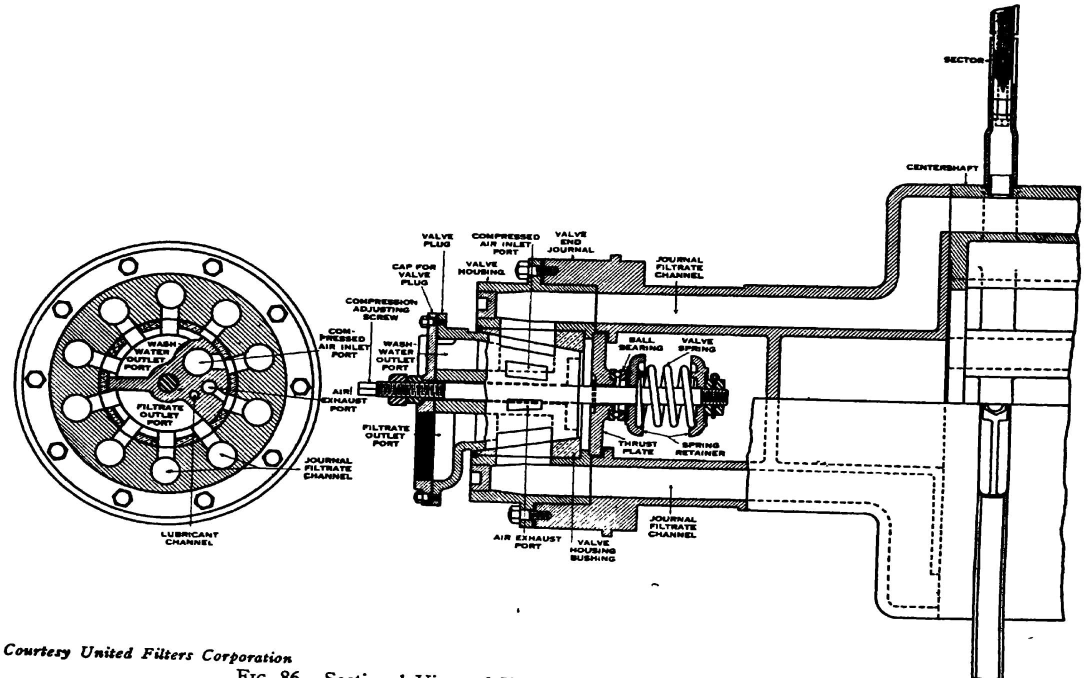
The drainage member must be rigid and a true plane. For these specifications corrugated wood drainage boards or cast-iron members are preferable to wire screen. The need of these specifications are apparent if the scrapers dislodging the cake are to function well and not dig into the cloth.

It is equally important that the radial rods be normal to the axis and in true alignment. It is often necessary to slightly bend these arms to obtain this alignment and then spot weld them in place so as to secure them. Apropos of this, it should be noted that only small wrenches should be used to back off the nuts that hold down the peripheral aligning clamps. If a nut rusts to the shaft a long-handled wrench may provide enough leverage to break the weld at the base of the rod. Resetting the rod is a mean job after the machine is installed and working.

When assembling the leaves in the disc the outlet nipple rests on a sealing gasket. This is generally soft rubber and there is no demand that the clamps be made up more than will insure proper seating of the nipple on the gasket.

The filtrate conduits register with a cored casting in which is incorporated the bearing for the shaft at the valve end, and the rotating member of the valve. The latter is fitted with a renewable internal cone sleeve. This is drilled to register with the terminals of the conduits. The stationary member of the valve is a cone to fit the interior of the sleeve of the rotating member. These parts fit in a manner very similar to the standard plug cock. The stationary part is ported with provision to catch filtrate, to separate wash water and to admit compressed air. An additional port to vent the compressed air is very serviceable if the filter cloth is tight and tends to deflate too slowly. The two surfaces of the cones are kept in self-grinding contact by a heavy spring located inside on a central rod. Pressure is thus even all over and any wear is taken up automatically by the tension of the spring. This valve is one of the best and most serviceable features of this filter.

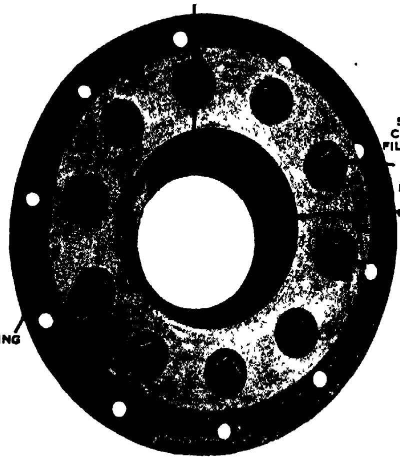
The container in which the discs rotate is unique in its design. Note that cake is built on vertical surfaces and provision must be made to take care of the discharge from the adjacent leaves. The required space between the leaves is obtained by making separate narrow pans for each disc,



Courtesy United Filters Corporation

FIG. 86.—Sectional View of Valve—American Continuous Filter.

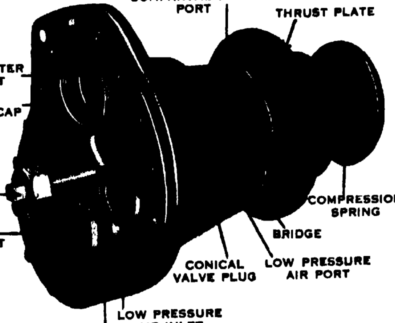
One of the best features of this filter is the self-seating valve. Any wear on the contact surfaces is compensated for by the valve spring which draws the stationary cone into constant contact with the rotating member.



Courtesy United Filters Corporation

FIG. 87.—Rotating Member of Cone Valve—American Continuous Filter.

The ports in the valve through which the filtrate (from the respective filtrate channels) drains into the stationary member, are rectangular, thus insuring positive cut-off as well as ample drainage.



Courtesy United Filters Corporation

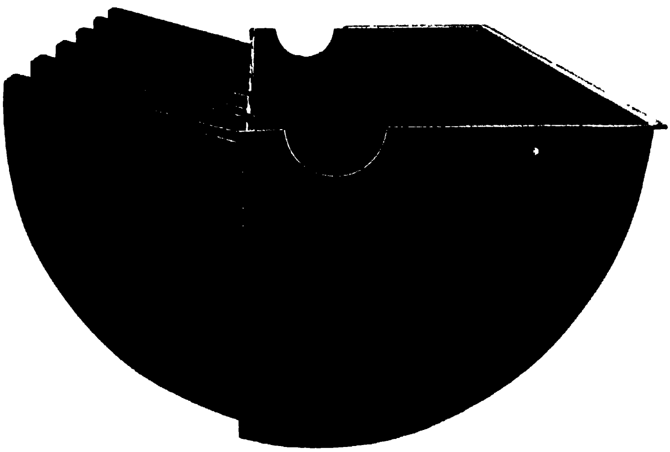
FIG. 88.—Stationary Member of Valve—American Continuous Filter.

The ports collecting filtrate, wash effluent, and for reverse compressed air are well proportioned and provide ample drainage. The bridges dividing the ports are substantial and easily machined and ground into positive contact with the internal cone of the rotating member.

which are flanged to the main pan common to all the discs on the washing side of the machine. Spacing the discs on any desired centers provides any discharge space desired. The cake thus falls between the pans into a longitudinal hopper located below the machine.

Scrapers for dislodging the cake are generally augmented by stiff wire fingers or conical rollers held in contact with the leaves as they come into the discharging zone. These latter aids are easier on the filter cloth and reduce wear. Where the rollers are used the scraper removes the cake picked up by the rolls.

To wash solubles from the cake requires delicate dewing of the wash water upon the surface of the cake. Note that points at different radial distances travel at different lineal speeds so that at the periphery far more



Courtesy United Filters Corporation

FIG. 89.—Sludge Container—American Continuous Filter.

Space is required between each leaf for the discharge of the cake, consequently the container on the discharge side of the machine consists of a series of pans. On the ascending side the container is an open tank which allows unlimited cake building and a better opportunity for circulation of the sludge.

water is required than at the base of the leaf. Again, the cake is deposited on a vertical surface and excess water falls directly into the container. The design, therefore, is a nice distribution of spray nozzles playing upon each side of each leaf and varying intensity to take care of the area wetted. Good atomization is essential and it is now standard to hood over the washing section and thus prevent driftage of the fine spray. The latter has, however, the disadvantage of obscuring the work of the atomizing nozzles and hence lessens the observation control of the operator.

Operation.—Like all continuous filters the operation of the American Continuous Filter is confined to starting up, adjustments, and replacing filter cloths.

Starting up is practically identical with the Oliver and other rotary drum filters and reference to the preceding chapter will acquaint anyone with this.

Adjustment in the positions of spray nozzles is generally necessary only at starting, while the amount of water supplied by each nozzle is seldom changed except for a marked change in the filtrability of the material in hand. Varying vacuums are sometimes required if the product changes, but otherwise this requires no adjusting.

Replacing worn or broken filter cloth is radically different from that in other vacuum continuous filters. All of the sector shaped filter leaves are alike and interchangeable and it is a point in the design of this filter that any leaf will fit in any part of the machine. Consequently, if a defective leaf is located, that section can be removed and any one spare can be substituted. Detecting a faulty section is difficult unless the trouble be of a major character, and so it is usual practice to change all leaves at the same time.

The first operation is to remove the nuts on the ends of the radial rods. Care must be taken to remove the nut without breaking the spot weld holding the rod on the shaft. Also, the thread must not be crossed or mutilated. As the nuts are taken off the clamps are removed and each leaf pulled out. After all the leaves are removed the rubber washers that seal the ends of the outlet nipples should be removed and care taken that cake does not lodge in the recesses. The old cloths are then taken off the leaves and new bags substituted. As soon as all the leaves are recovered and new washers inserted, for sealing the outlet nipples, the reverse operation is required.

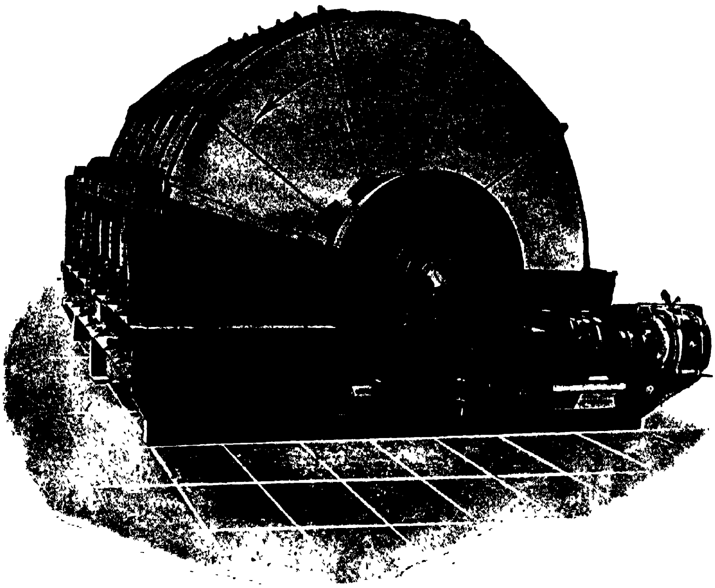
This differs from removing wire-winding and filter cloth of the rotary drum filters, but is a considerable task also.

Layout.—There is nothing specifically different in the layout for this type of machine other than the hopper collecting the discharged cake. This must be located under the filter and means either that the machine must be set up off the floor or the hopper run under the floor. Otherwise, reference to the typical layout for continuous filters as described in the preceding chapter will suffice.

Advantages.—The principal and distinct advantages of the American Continuous Filter lie in the (1) added area of filter surface obtainable per unit floor space, over drum machines, (2) it is practical to build multiple disc machines with areas far in excess of those practical in the drum type, (3) the main operating valve being a self-seating cone valve is a positive non-leaking valve and is better mechanics than the flat disk valves of the usual drum filters, (4) the sectionalized design means that each individual part is a relatively small weight and consequently transportation in isolated localities is easy, (5) no wire winding is necessary and hence the effective filter area is always maintained.

Drawbacks.—(1) Washing soluble from cakes is an approximation only in these machines. In practice it is too difficult to make the nice and delicate adjustment necessary for uniform washing of the cake. (2) Agitation of a far more violent sort is required if a uniform cake is to be built

over an entire leaf. Only the periphery of the leaves dip down into the bottom of the pan, while the area of short radius distance is only submerged near the top of the liquor in the container. Having so many individual sections, it is necessary that a good job be made of assembling the filter sections or else leaks occur difficult to locate. (3) Covering the leaves requires first, sewing the bag, then inserting the leaf in it and finally clamping the U-shape on top. Multiplying this for each section means



Courtesy United Filters Corporation

FIG. 90.—Large Size American Continuous Filter.

Having no wire winding to hold down the filter cloth and requiring reverse compressed air for discharging, made the use of scrapers against the cloth risky and led to the adoption of cone rollers, against which the cake is pressed by the reverse current. The adhering cake is then discharged by a scraper resting against the rollers. For best discharging, the cake thickness should be uniform and sufficiently plastic to adhere to the rollers.

very little saving over recovering drum filters. Positive alignment of the leaves is necessary and too often the aligning rods give way at the shaft before the nut on the end of the rod unloosens. The rod is replaced but seldom spotted correctly.

A nut on a thread that dips down into a muddy and often corrosive liquor and then rotates out into the air, proves a hard proposition to unscrew. A simple remedy to this drawback would be to use a cap instead of a nut. The thread would then be enclosed and protected from corrosive liquors.

(4) The ballooning effect on admitting reversed compressed air is often excessive and the discharge feature is hardly an advantage compared with drum filters.

(5) As the dewatering effect is the same in this machine as in the rotary drum filters or pressure leaf filters, the moisture content in the discharged cake is high when compared with the compressed cake in plate and frame filters.

The American Continuous Filter is an original mechanical design of a continuous vacuum filter but the principle of operation is identical with the drum type and consequently its work is practically the same as obtainable in the drum machines.

The two main disadvantages are: high moisture content in discharged cake, and the ineffective wash. It was in an endeavor to better this work that the FEinc Cake Compressor was developed, which later made possible the FEinc Filter.

Applications.—Being a vacuum continuous filter, this machine is, like vacuum drum filters, applicable to free-filtering solids or thickened difficult materials. Its washing efficiency does not compare with pressure leaf filters and its use is confined more to liquors requiring dewatering than to those from which the cakes must be washed. The novelty of the American Continuous Filter is more in its mechanics than in its operating features and, consequently, its particular application is where saving space required by drum filters is paramount, especially where large filter areas are necessary to handle big tonnages per unit.

Summary.—The American Continuous Filter rounds out a line of plate and frame presses and pressure leaf filters so as to give the United Filters Corporation a complete variety of filters. Its advent marked a new attack on the mechanics of a continuous filter. It was followed by a simplification of the mechanics of the drum filters together with the cake compressing device for the better washing and dewatering of the cake formed on them in the FEinc Filter and Cake Compressor, grouped as FEinc Apparatus in our next chapter.

Chapter VI.

Section III—FEinc Apparatus.

The Filtration Engineers Incorporated, started in 1919 as consulting engineers specializing in industrial filtration. In bettering filter work for some of their clients they developed a line of products known as FEinc Apparatus. These include Cake Compressor, Non-Atomizing Wash, FEinc Filter and FEinc Drying System.

FEinc Filter.—When the FEinc Cake Compressor and Non-Atomizing wash were demonstrated practical successes, they were followed by the FEinc Drying System. This, in brief, is making conveyable cakes built up on rotary drum filters and carrying the cakes through a drying atmosphere. This combination of filtering and drying, with its new method of discharge of the cake, gave rise to the FEinc Filter, a rotary drum filter of simplified mechanical construction.

This drying system is described under "Combination Filtering and Drying" in the chapter on "Relation of Filtration to Other Chemical Operations" in Part IV.

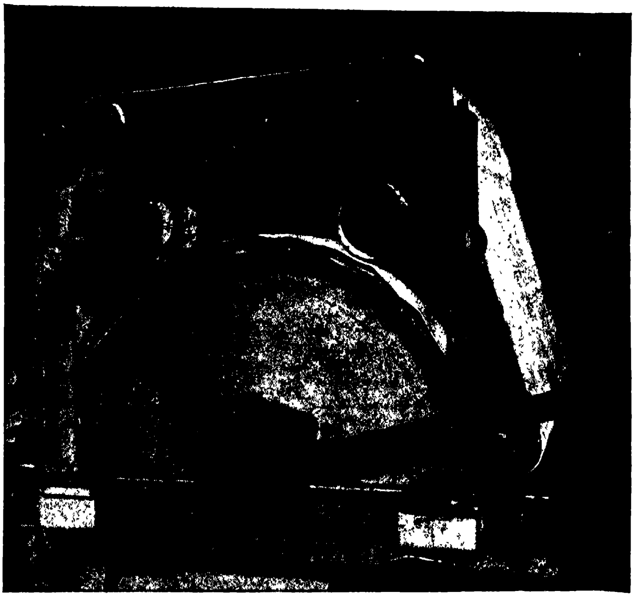
For convenience in following proper sequence in the development of the FEinc filter, the compressor and atomizer are first described here. These devices find proper place here as they pertain to drum filters.

FEinc Cake Compressor.—One of the earliest improvements was the FEinc Cake Compressor. This had its origin in an endeavor to decrease the moisture content of the cake discharged from continuous drum filters. Wet cakes have been an obvious weakness in the operation of these filters for years, but the scheme of a simple mechanical construction was hit upon when maintaining equal peripheral speeds with the surface of the cake and the compressing medium. The initial success with the first crude machine showed that the principle was good and that the advantages were not confined to better cake dewatering only. Cracking of the cake was reduced; less vacuum pump capacity was required; and it was found possible to operate these filters with low vacuum pressure for filtration and a higher vacuum pressure for dewatering. The latter has immense possibilities, for it is evident that when the resistance has been built up during the filtering cycle, an increased force helps extract the moisture in the voids of the cake when dewatering it.

Design.—The main essential in the cake compressor design is the continuous compressing belt which falls upon the ascending cake and is stripped from the descending cake to return over idle rollers for repeat operation. This endless belt rides over the exposed face of the drum from one liquor level over to the point of cake discharge. It then rises and,

carried by idlers set in a frame above the drum, returns to the rear liquor level.

The belt travels over four idlers: (1) located across the face of the drum just above the liquor level where the cake emerges from the tank; (2) across the face of the drum above the discharge of the cake; (3 and 4) on top of the frame over the drum.



Courtesy Filtration Engineers, Incorporated

FIG. 91.—FEinc Cake Compressor.

In order to effect the best dewatering of the cake on a drum filter, the maximum shrinkage in volume with the attendant minimum void space in the cake should be obtained. The endless belt on this device has this function. Its compressing effect is intensified by the compression rollers which are graduated in dead weight so that the cake is not ruptured by the compressing action. The belt leaves the cake with the full vacuum pressure on the cake and consequently leaves all the cake intact on the filter. The belt is under only a slight tension sufficient to insure positive alignment. The cake compressor prevents cracks and enables the filter to be operated with a low vacuum during filtration, and a higher vacuum during dewatering.

Compression rollers squeeze the belt on the cake upon the drum. These rollers are idle cylinders of varying weights resting on top of the belt where it is in contact with the cake. These rolls serve to intensify the compressing action of the belt and are located at different points on the drum, depending upon the material being handled.

FIG. 92.—FEinc Filter—Cake Compressor.

The endless compression belt is made of a woven fabric, the specifications of which vary for the class of material being handled. Neither the belt nor any of the rolls are driven so that the belt travels in positive synchronism with the peripheral speed of the cake. The flexible belt conforms to any variation in cake formation, and the compression rolls are individually loaded so as best to compress the material in hand. No cake sticks to the compression belt and none ever touches the compression rolls. The compressing force is normal to the drum so that the load is taken up in the bearings.

The belt is rotated by the filter drum *at its own rate, not driven* by any separate drive. The pulleys over which it moves are idlers located above the drum convenient to bring the belt back over the filter. One of the pulleys is carried in bearings which are made adjustable to center the belt with the drum. Suitable standards of any convenient construction (cast iron is generally used) carry the pulleys and the arms of the compressing rolls. The standards can be attached to the container of the filter or carried on supports separate from the filter.

The operation of the cake compressor is, therefore, simple, adjustment being required only at infrequent intervals.

Layout.—The addition of a cake compressor increases the over-all height of the filter and, in some cases, requires modified construction where I-beams or other obstructions come close to the filter. In some filters the flanges, around the top of the container, will not carry the standards of the compressor and in such cases the standards must be supported from the floor.

Advantages.—The principal function of the cake compressor is in the reduction of the moisture content. Cakes are obtainable with continuous filters equal to and in some cases better than with plate and frame filter presses. With some materials the dryness of discharge will be 25 per cent and with others as much as 50 per cent less than that obtainable with the same filter without the compressor. Better dewatering in using the compressor is largely due to elimination of cracks. Cracks are short circuits through which air rushes without displacing moisture in the cake, consequently, eliminating cracks means less pump requirement and (as all the air does work of dewatering)—drier cakes.

Reduction of pump capacity will range from 20 to 90 per cent of that required when working without the compressor.

Compressing the cake increases the adherence of the particles forming the cake so that the cake solidifies and discharges as a sheet. Reverse compressed air lifts all of the cake from the cloth, effectively pushing out even that which sinks into the nap of the cloth. Eliminating cracks makes it possible to use different vacuum pressures while filtering and while compressing. This advantage is no small factor in the better dewatering effect obtainable with this device.

Drawbacks.—The cake compressor is an accessory to the filter and is an added encumbrance when recovering the filter with new cloth, although removing the compressor belt and lifting up the compression rolls only takes about ten minutes. Covering over the exposed part of the drum decreases facility in observing the filter and the operator is confined to the point of discharge for observing the work of his filter. The compressor belt is made of wool or cotton, and must wear out. This adds to renewal expense of the filter.

After the cake compressor had been successfully demonstrated, it was desirable to be able to wash solubles from the cake as well as to compress it. A modification in the cake compressor gave rise to the non-atomizing wash.

Non-Atomizing Wash.—The difficulties encountered in effectively washing cakes on a continuous drum filter where the same material varied from day to day in its filtering characteristics, demanded a better means of washing the cake on this filter. Pressure leaf filters could handle this material since the washing could be lengthened or shortened to meet the variation in the material. The idea of submerging the cake in wash water so that the surface of the cake has all the water it can take, gave rise to the FEinc Non-Atomizing Wash.

This device is a modification of the cake compressor wherein the heavy canvas belt is replaced by an absorbent belt and a water supply fed to the surface of the absorbent belt while it is in contact with the cake.

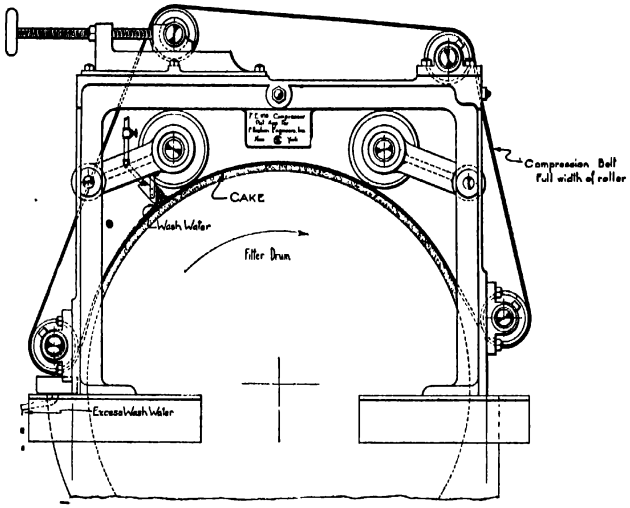
Design.—In this device there are two fundamentals in the design,—the washing belt and the distribution of the wash water.

The absorbent washing belt must be strong enough to be used as a continuous belt and porous enough to allow free passage of the wash water. Burlap, heavy cotton blanket cloth, wool felt, etc., are the leading fabrics for this belt. Few of them are strong enough or of short enough nap to be used without backing them with a more durable fabric. In consequence, it is standard to sew a backing of light but strong drill, an open twill or equivalent weave, to the absorbent fabric. The combined cloths are then made up as a standard compressor belt and assembled as such.

The wash water is distributed at the zenith of the drum or at any point on the ascending belt. The scheme is to spill the water on the belt in excess of what the cake can take so as to overwet the belt, as a sheet of water sweeping down the ascending belt. This water is not atomized, but spilled on from an open trough as a weir, or through a sawtooth overflow,

or from a pipe with large perforations. No pressure is required, a gravity feed tank with steam coils located immediately above the filter being a good means of obtaining hot water for wash when needed. No strainers for catching extraneous dirt are necessary as all openings are large and not easily clogged. There is no danger of spray drift and hence no side curtains are required.

It is necessary to catch the excess water that runs off the belt, principally at the sides at the lower idler. This collecting trough is a simple



SIDE ELEVATION

Courtesy Filtration Engineers, Incorporated

FIG. 93.—FEinc Filter—Non-Atomizing Wash.

Submerging the cake under wash water is the positive means of washing, as then every square inch of the surface is equally wetted. This is accomplished here by using an absorbent compression belt and feeding water from an open trough, located under the first compression roll, in excess so that the collecting trough under the lower idler carries it away. No atomizers are used.

galvanized iron pan with outlet pipe carrying the water back to the source of supply or running it to waste down the sewer.

The location of the water distributing trough depends upon the amount of wash required, as it is possible to extend the washing zone well beyond the zenith of the drum or to limit it to a very short application on the ascending drum. The longer the washing arc, the shorter the drying arc and the greater the moisture content of the discharged cake. Compression rolls are located beyond the point where the water is applied (so as not to obstruct the descending sheet of water) and vary in weight progressively, as in the cake compressor design previously described.

Operation.—The operation of the non-atomizing wash is similar to the cake compressor save in the point of application of the wash water and the amount of water to be applied. When washing cakes, the soluble content of which is easily removed, the distributing trough is located well down the ascending drum. Enough water is supplied to provide a constant excess flowing from the collecting trough. Having an excess of water and operating with differential vacuums on the filtering and washing arcs means that there is high percolation of the wash water, which effectively washes the cake irrespective of variations in the filtering characteristics of the material being handled.

Where an exacting wash of the soluble from a retentive solid is required, the wash water is applied at the zenith and the first compression roller situated on the descending side of the drum. This increases the arc of washing but still maintains the principle of an overwetted cake which is employed in leaf type filters and is the secret of success.

The wash water should be clean or otherwise it will filter through the washing belt and in time clog it. This does happen when using weak wash from a previous filtration where the filter cloth has failed and cloudy filtrate is obtained. In such cases it is found that to replace the cloth periodically with a cleaned belt is better than endeavoring to automatically clean the cloth on the machine.

Layout.—When using cold water the layout is a simple piping of the cold water to the distributing trough and a return piping of the excess water to the sewer. When weak liquors are used as wash water, the receiving tank for these liquors should be located so that the excess from the collecting trough runs back by gravity to it.

When hot water is required and no hot water lines are available in the plant, a small tank located above the filter in which steam coils or jets are provided, comprises the simplest means of laying out the reservoir and piping for this. In this case the excess hot water represents a loss but it amounts to but a small part of the water consumed, unless it be pumped back to the supply tank.

Advantages.—Increasing the amount of water in the given arc of washing by means of the non-atomizing wash has delivered cakes containing only half of the soluble content as when washed by atomizing nozzles. Increasing the filtering force during the washing arc by raising the vacuum pressure increases the percolation and hence the displacing of the soluble.

Adding compression to washing the cake decreases the moisture in the cake and consequently lowers the soluble content in the discharged cake.

Adding more water than the washing belt will take is a simpler control than attempting to gauge just the amount of water the cake will take.

Eliminating atomizing nozzles reduces troubles incident to atomizers, namely, high pressure; straining water to prevent clogging; driftage of fine spray and pitting the cake.

Drawbacks.—The same disadvantages occurring with the cake compressor are present in the non-atomizing wash.

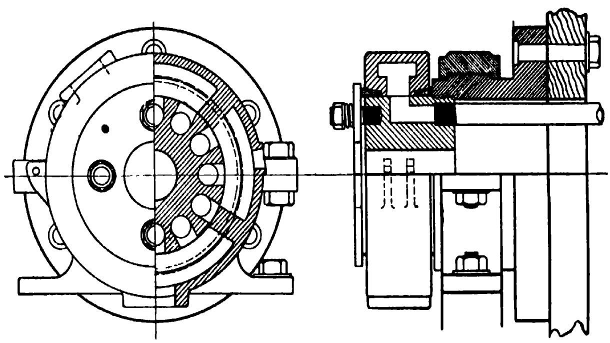
Using a muddy wash water filters the solids from the water and clogs

the washing belt. To block off the permeability of the water through the belt defeats the function of the belt and the whole scheme of things.

FEinc Filter.

Design.—The distinctive features of this filter are, (1) the new form of drainage, and (2) elimination of wire winding on the drum brought about by cutting out the use of reversed compressed air for discharging. Omitting the compressed air port reduces the requirements of the design of the valve, and (3) made possible a new type of non-grinding valve.

The new drainage member is of smaller volume than the usual for the reason that the FEinc Cake Compressor is a standard accessory with this



Courtesy Filtration Engineers, Incorporated

FIG. 94.—FEinc Filter—Automatic Valve.

Discharge on this filter is effected without any reverse compressed air so that a different attack is feasible in the design of the valve. The collecting ring is not in positive contact with the rotating hub save at the bridges, the side leakage being prevented by packing somewhat similar to stuffing box design. Each compartment pipe delivers its filtrate to the periphery of the hub instead of to its face.

filter so that the drainage area, pipe and port areas are not designed to accommodate the air capacity that is otherwise drawn through cracks in the cake. The drainage is ample even when reduced to 3/16 in. In designing the drainage of a compartment it is necessary that the filtrate be unobstructed in its flow from points remote to the outlet piping as well as from points close to the outlet. It is a simpler assembly job in manufacture of the filter if the drainage member can be secured made up instead of having to be fabricated in the shop. These specifications are met in the tubular spiral woven screen quite similar to modern bed spring construction. This drainage member can be made up of any ductile metal such as iron, bronze, monel, aluminum, etc.

The cake compressor, we have learned, compacts the cake and makes its particles more adherent. This point is taken advantage of in the discharge of the cake by scraper methods, for it is found that the scraper

will dig into the leading edge of the cake of each compartment and then the entire cake slides over the scraper, leaving the cloth in a fresh and clean condition without any compressed air assisting the discharge. It is required simply that the vacuum be cut off and atmospheric air be admitted to the compartment. For this reason then, no wire winding is used on the FEinc filter, unless it be wound on wide centers as a protection against the operator setting the scraper too close to the cloth.

There is another point in the design of this filter bearing on the elimination of reversed compressed air. The valve controlling the operation of each compartment functions now as a vacuum breaker. This means that all points of leakage are from the outside in, consequently a simpler valve is possible. The first important change from the valve used on the familiar drum type filters is that the outlet pipes from the compartments terminate on the periphery of the rotating hub rather than at the face or end of the hub. The hub is larger in the bearing than it is at the point where the outlet pipes end. A wedge shaped collar fits against this shoulder, emulating the gland used in standard stuffing boxes. The stationary member of the valve is an enlarged collar that easily slips over the hub, with a machined surface of corresponding slant to the wedge collar so that this member of the valve fits against the wedge collar. This machine surface does not continue through the valve but extends until it meets a projection that fits the hub with only a slight clearance. Several rings of ordinary packing are placed against the wedge collar and are taken up against the projection when the valve is made up. In brief, this is a stuffing box packing, free from leakage troubles due to the slow speed of rotation and the fact that leakage is from the outside in.

The annular stationary collar of the valve is provided with a large internal groove for the collection of the filtrate. This groove straddles the outlet pipes effectively drawing all filtrate from the pipes. Wearing bridges are the dividing members between low and high vacuum, atmospheric air and cloudy filtrate and define the ports of the valve.

The outer edge of the stationary member is machined just the reverse of the back edge and a similar packing and wedge collar form the sliding joint.

The packings are made tight by tightening a face plate that bolts on to the end of the rotating hub. The face plate extends so as to bear against the outer wedge collars. As the outer wedge collar moves in, it presses against the outer packing and moves the outer valve member so as to compress the inner packing. The packings are heavily greased with a graphite mixture and after a few rotations are well sealed, leakless joints.

Having no metal to metal surfaces and only the easily replaceable bridges as the wearing parts marks this valve as a radical advance in valve design. It will be understood that the bridges are made of softer material than the rotating hub so that all wear occurs on them and none on the hub.

The outlet pipes are distributed around the periphery of the collecting collar so that there is room for a greater number of outlet pipes. Where the filter is used as clarifying as the principal function there is a port and outlet for the first filtrate obtained as the compartment re-enters the liquor.

This is designed to take any cloudy filtrate that may be produced until a coating is formed over the cloth. From this point on only clear filtrate is obtainable and another port and outlet take the filtrate then produced. This construction guarantees true clarity of the main filtrate, as the initial runnings are returned to be refiltered.

The drum is secured to an extra heavy shaft, ample room in the face of the hub accommodating large shafts, by internal spiders or supports. The ends of the drum are closed. These ends or heads are not necessarily leak proof joints but sufficiently tight to prevent fresh liquor surging in and out of the interior of the drum.

The heavy shaft is carried in standard bearings which in larger machines are carried on independent supports. This design insures better alignment of the shaft without excessively strengthening the end walls of the container which can be designed for internal loading of liquor only, and removes the source of vibration that so often opens up the joints on the containers of large machines.

Agitation in the filter for the average material is obtained by feeding the filter at the bottom and overflowing at the top. This uprising current is effective provided the clearances around the drum are a minimum and the excess unfiltered liquid a minimum. For this reason the container of the filter is only slightly larger in diameter than the diameter of the drum plus the cake. A distributing channel with baffle plate prevents the impinging of the liquor upon the cake and an overflow trough catches the overflow liquor. In addition to providing agitation this construction insures constant liquor level without any control on the part of the operator.

One of the operating features of the FEinc filter is its ability to discharge completely the thinnest cakes. This is due to the vacuum discharge of the cake when the solids adhere to the compressor belt rather than to the filter cloth. This interesting method of discharge is effected by a proper proportioning of the porosity of the filter cloth and the compressor belt, so that the vacuum breaks through the filter cloth to the surface of the cake before it breaks through the compressing canvas. The design of this lies more in the design of the compressor than in the filter, but is rightly considered here as the combination comprises the unit.

The point of tangency for the compressor belt on the discharge side is lowered over that when a standard compressor is used, so that the vacuum is broken a full compartment width above it. All the cake adheres to the compressor belt and can be scraped off as it turns around an idler, as it ascends on its return journey or at any other desired location.

In the design of the filter the ability to discharge thin cakes has immense importance. The rotative speed is no longer the important factor. The filtering arc is determined by the angular submergence of the drum, but the time of immersion is governed by the characteristics of the curve. The filtering time can now conform to the economical limit as set by the curve. The angle for submergence is defined in relation to the washing and dewatering requirements. The point of discharge is not fixed by the angle of incline of the scraper, which must be set tangent to the

drum at the point of contact as no scraper on the drum is necessary.

These points make the design of the filter convertible to the characteristics and requirements of the material in hand.

Operation.—The operation of the FEinc filter is analogous with any rotary drum filter equipped with a FEinc Cake Compressor. Eliminating reverse compressed air is a simplification in the operation and eliminating the spiral winding lessens the work of renewing the filter cloth.

The alignment of the compressing belt and maintaining even tensions in the belt are complications to the operation of the usual drum filter. Having to uncouple the compressing belt and to lift the compressing rolls out of contact are additional complications when recovering the filter. The infrequency of this operation offsets this defect.

Circulation by underfeeding and overflowing maintains effective agitation for all liquors save those of the most rapid settling, since the excess volume surrounding the drum is a minimum and the change of liquor, by an uprising current, constant. An oscillating agitator is provided when quick settling materials are handled. Maintaining a positive overflow provides an undeviating liquor level in the container. This is a fool-proof provision and eliminates one of the customary duties of the operator in adjusting a liquor inlet valve.

The rotative speed is fixed for the application to any one material. In designing the unit, however, wide latitude in the speed of revolution is possible since any cake thickness is dischargeable. The proper rotation is, therefore, set in accordance with the economical limit of filtration and without regard to the matter of building up a substantial cake thickness.

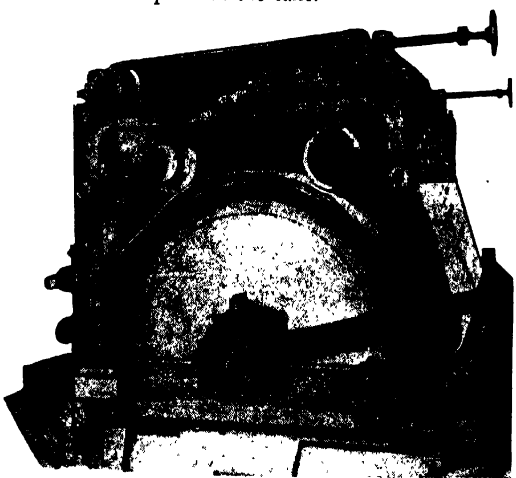
Since the cake compressor seals all cracks in the cake after its emergence from the liquor, it is practical to work at a limiting vacuum pressure, usually fifteen inches of mercury, while filtering and to operate with a higher pressure, twenty inches up, while dewatering. This mode of operation tends to produce the driest discharge since the increased working pressure is an added force to extract the moisture from the deposited cake. The same increase of pressure is standard when washing the cake, as this greater force increases the percolation through the cake without producing short circuits for the washing water.

When washing, the arc of rotation for applying the water is easily varied so that the desired wash is obtained. The wetted belt can extend well down the descending side of the drum or, for a small arc, on the ascending belt. The exact length of the arc is variable with the material in hand and should be determined by trying to locate the minimum arc for each installation.

The fundamental underlying the washing operation on this machine is that more water shall be applied than is required. This emulates the washing by submergence of leaf filters and insures all the advantages of displacement washing. There are two requisites in order for this to be successful; first, that the belt on the compressor be absorbent to hold the water and of low resistance to give up freely the water to the cake; and second, that there be a positive excess collected by the wash collecting

trough under the lower idler. This excess need not be large, but must be positive.

For dewatering, the compression of the cake must not disrupt the cake. The point of initial contact of belt with cake must be prior to any cracking of the cake, and yet not too soon so as to squeeze out the cake from under the belt. The drier the cake, the heavier the compression, so that succeeding compressing rolls exert greater pressure, but always within the limit of disruption of the cake.



Courtesy Filtration Engineers, Incorporated

FIG. 95.—Vacuum Discharge—FEinc Filter.

This is a modification of the FEinc Cake Compressor by which all cake on the drum is made to adhere to the compressor belt. By this method cakes 1/16 to 3/4 of an inch thick are completely discharged. The cake adhering to the belt can be scraped at any convenient location. Inasmuch as the compressor belt is not a filter medium, the cake does not have to be completely cleaned from the cloth, and the scraper therefore can be set away from the belt. This method of discharge makes possible maximum submergence of the drum (75%) for clarifying duty as the position of the scraper is independent of the drum.

When handling free filtering solids a modified operation can be worked to give a very low moisture content. It will be remembered that the cake lying close to the filter cloth is denser than the cake near the outer surface. The dense cake carries less moisture, consequently a scraper located under the liquor is set to remove the outer cake. With the cake compressor no increased vacuum capacity is required as the early tendency of the cake to crack under these conditions is prevented.

Discharging the cake can be effected by either of two methods, scraper or vacuum discharge. When using the scraper it is not necessary to set it close to the filter cloth as the compacting action of the cake compressor makes the particles of the cake adherent, so that the whole cake is deflected

from the drum even without reversed compressd air. Eliminating the air pressure reduces the moisture thrown back into the cake and obviates any mechanical scheme of holding down the cloth. On wide face filters a spiral winding on one foot centers is advisable to guard against the operator's setting the scraper too close on one side and thereby cutting the filter cloth. With vacuum discharge, wire winding is positively unnecessary.

Vacuum discharge is effected by making all the cake adhere to the compressing belt by breaking the vacuum from the filter cloth side of the cake before releasing it on the compression belt side. It is obtained in a most simple manner,—the porosity of the filter cloth must be less than the porosity of the compression belt and the point of tangency of the compression belt, leaving the drum, must be a full compartment width below the point of vacuum cut off to the discharging compartment. The cake adhering to the belt can be scraped from it at any desired location and it is not necessary to scrape the belt clean for it is not a filter medium and any residual cake does not set up a resistance to the flow of filtrate.

Layout.—Save for the location of the discharged solids, which is determined by local conditions, the layout is practically the same as for the usual rotary drum filter, equipped with FEinc Cake Compressor and Non-Atomizing Wash. It is standard practice to feed this filter at the bottom and maintain a constant overflow back to the source of supply.

Advantages.—The simplicity of design stands out as a prominent advantage in the FEinc filter. The elimination of wire winding on the filter cloth, the easily replaceable wearing bridges in the valve, and the ease of renewing the drainage member are features of the simplicity of its design.

Its broad application irrespective of filtering characteristics, washing or dewatering requirements is truly an advantage.

Its capacity and economy are high. No area is blocked by wire winding. The rotative speed is determined by the economical filtering cycle of the material in hand so that the drum is generally rotated faster than are the usual continuous filters. The submergence is fixed in relation to the arcs of rotation necessary for the desired washing and dewatering as the discharge is independent of the position of the scraper; hence, higher liquor levels prevail than is customary. Uniform cakes are built up as the uprising current of the liquor fed to the container at the bottom and overflowing at the cleaned cloth side insures against classification, the cleaned cloth dipping into a uniform mixture of coarse and fine particles. The compressor irons out cracks that form short circuits so that the vacuum pump requirements are smaller than usually required.

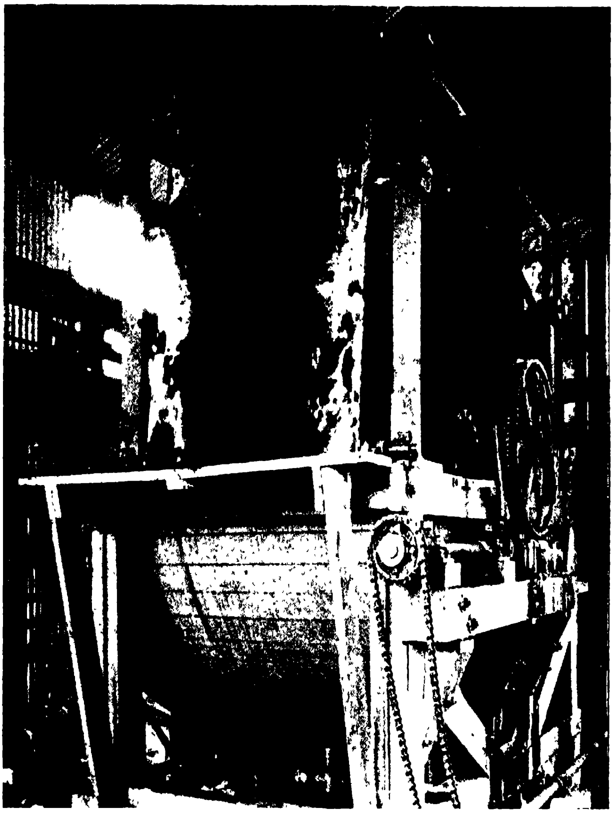
Using no reverse compressed air reduces the moisture in the discharged cake by eliminating the filtrate usually blown back.

By compacting the cake so that the particles adhere to one another, all the cake is completely discharged, being pulled radially from the filter cloth.

The advantages of the FEinc Cake Compressor and Non-Atomizing

Wash are realized in the FEinc filter as they are an integral part of the filter design.

Maintaining a constant liquor level by overflowing an excess is a fool-proof means of controlling the submergence of the drum.



Courtesy Filtration Engineers, Incorporated

FIG. 96.—FEinc Cake Compressor Applied to Large Rotary Filter.

The simple mechanics of this device makes possible its application to rotary drum filters irrespective of size. The belt may be stained by the material being handled but none of the cake adheres to the belt.

The filter cloth is quickly removed and the drum easily recovered, since no wire winding of the filter cloth to the drum is required.

Drawbacks.—As with all vacuum filters, volatile and supersaturated liquors are not amenable. Liquors heated above the boiling point of the vacuum employed are classed with the above.

The floor space and head room necessary with drum filters is a disadvantage as compared with disc filters.

Applications.—The FEinc filter is adaptable to a variety of materials. The discharge from it being complete, irrespective of cake thickness, it is practical for any liquor save one containing only a slight turbidity in which case clarifying filters of pressure leaf or plate and frame presses are better.

By reason of the dewatering effect of the cake compressor, wherein the moisture content can be lowered to that obtainable in plate and frame presses, this continuous filter is applicable to those materials which have been handled in plate and frame presses exclusively.

With the increased washing efficiency of the non-atomizing wash, even those materials requiring an exacting wash are handled on this machine.

Save for those liquors on which no vacuum machine is applicable (as hot, supersaturated, volatile, etc., liquors) the FEinc filter approaches universal application. It will handle free filtering products, slow cake building materials and thick or thin slurries.

This filter and the cake compressor form part of the FEinc Drying System, a combination of filtering and drying, which is discussed in the chapter on Relation of Filtration to Other Chemical Plant Operations.

Chapter VII.

Special Filters and Clarifiers.

No one filter is universal in its application, for, while filter presses have been used for practically every use, no one is content to use these machines who can make another machine work. In order to overcome the disadvantages of plate and frame press operation, or to improve on the operation of some of the modern filters, some specially designed filters and clarifiers have been developed and exploited. Those of most prominence are:

1. Dorr Apparatus (Continuous Decantation and Classification Machines).
2. Merrill Filter (Sluicing Discharge Plate and Frame).
3. Atkins-Shriver (Automatic Discharge Plate and Frame).
4. Burt (Rotary Pressure Filter).
5. Zenith (Rotary Hopper Dewaterer).
6. Oliver (Continuous Sand Table).
7. "FEinc" (Automatic Discharge Acid Filter).

"Dorr Apparatus" embraces the Dorr Classifier and the Dorr Thickener as being within the scope of our discussion. Too often emphasis is placed on the competitive character of the Dorr Thickener with filters. The thickener is for the most cases a clarifier delivering a clear, sparkling overflow and, as such, fulfills one of the functions of a filter. The settled solids are, however, dewatered by filtration so that the more liberal view is that Dorr Apparatus is complementary to industrial filters.

In one sense, the Dorr Classifier is a filter overflowing a partially clarified liquor. It is the best partial clarifier developed in America and is very rightly considered in a discussion of American filtration.

Briefly, the Dorr Thickener is a continuous settling device, whereby a clear supernatant liquid is delivered at one point and thickened solids collected at another.

The Dorr Classifier is a mechanical raking device, moving solids settled from the liquor up an inclined plane so that drained solids are collected at the top of the inclined plane, and semi-clarified liquor overflowed from the treatment tank.

The wide application of Dorr Apparatus far outstrips the application of any special filter and it rightfully deserves first place in this discussion.

The Merrill and Atkins-Shriver are self-discharging plate and frame machines. The Merrill discharges by sluicing methods, while the Atkins-Shriver ploughs out the cake dry.

The Burt is a rotary cylindrical filter,—the inner surface of which is coated with filter cloth so that it is an internal rotary filter.

The Oliver Continuous Sand Table is an adaptation of the principle of individual compartments continuously alternating from suction to compressed air (as developed in the Oliver Continuous Drum Filter) in a horizontal filter. Materials too granular to be applicable to drum filters are effectively handled in this machine.

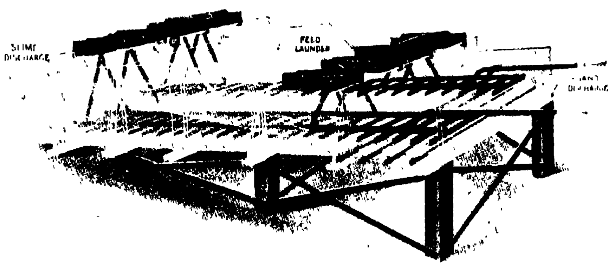
The Rotary Hopper Dewaterer is a development of the Industrial Filtration Corporation for the same purpose as the Oliver Sand Table,—i.e., to handle materials too granular to build up as cake on drum filters. It is best described as multiple Buchner funnels located on the periphery of the drum of a Zenith filter.

The FEinc Automatic Discharge Acid Filter was developed by the Filtration Engineers, Inc., at the end of the war to handle 98 per cent sulphuric acid. It is a conventional sand filter with coarse gravel as drainage member equipped with a removable lead or monel metal screen, which lifts the cake off the sand bed and mechanically discharges it away from the filter.

Chapter VII.

Section I—Dorr Apparatus.

The growth, strength, and potential possibilities of the Dorr Company as a body of chemical engineers is a striking memorial to the genius of its founder, J. V. N. Dorr. It might be nice to attribute this success solely to Dorr's personal work, but the progress of the Dorr Company has gone beyond the work of one man. Yet, the very organization which made this progress possible is in itself more of a triumph of Dorr's ability than any individual work alone could be. The history of this company could well be taken to heart by every manufacturer of chemical engineering apparatus. It is the recital of the familiar story of a good thing well done. The machines perform excellently and the Dorr engineers have served well.



Courtesy The Dorr Company

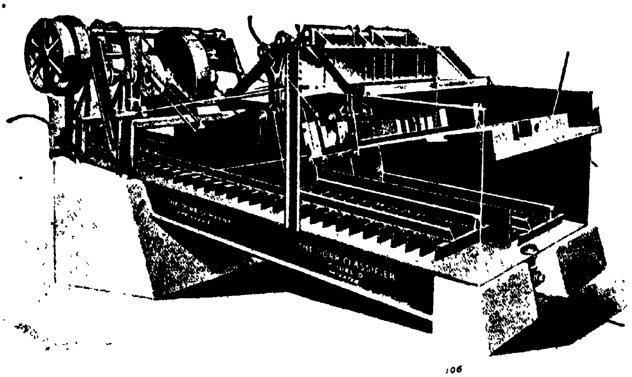
FIG. 97.—Dorr Classifier—Early Design.

The earliest designs of this machine incorporated the main essential of conveying the settled material up an inclined plane by means of the motion of the rakes—upward along the plane, backward above the plane.

Dorr was by education a chemist and early grasped the opportunity to go west and work in the laboratory of a mining mill. His attention was soon directed to the better separation of slimes from the sands in the wet grinding of the gold bearing ore at his mill. His distinct success in the development of the Dorr Classifier led him two years later to develop this thickener for a mill for which he was acting as a consultant. Again his genius for diagnosis of the elements of the problem and for simple mechanics resulted in success—the Dorr Thickener.

The chemical industry, as well as the mining industry, has many good reasons for feeling indebted to the introduction of the cyanide process of recovering precious metals. Moore developed his leaf filter in an endeavor to decrease the losses in cyanide tailings; Sweetland and Kelly invented their pressure leaf filters in an effort to increase the filter capacity when handling these same slimes, and Dorr equipment had its origin in the difficulties of separating and dewatering slimes.

There are a number of machines included among the products put out by the Dorr Company, but those most directly pertinent to the subject of clarification are the Dorr Classifier, which mechanically separates heavy from fine particles of suspension, and the Dorr Thickener which is a continuous decantation machine. These two, then, will be discussed here.



Courtesy The Dorr Company

FIG. 98.—Dorr Classifier—Standard Design.

Rugged construction, bearings of moving parts above the liquor, and simple mechanics mark the present design of this machine.

Dorr Classifier.—In the cyanidation of a gold bearing ore, the mined product is ground to a fine mesh in cyanide solution. Much of the ore is of a hard granular nature, the rest soft and slimy. The best means of treating these solids of suspension is to separate the coarse from the fine and extract the valuable solution from each separately.

Dorr set out to make this separation by a continuous machine and succeeded by the invention of his classifier.

Design.—The Dorr Classifier is fundamentally a rectangular tank with inclined bottom provided with a mechanical raking arrangement to convey any material settling to the bottom up the incline and to discharge it at the top of the tank. At the opposite end an overflow trough delivers the liquid carrying the non-settling particles.

Its development is a refinement of its mechanical construction, series operation and a combination of the thickener principle with the classifier.

In each case the keynote of success is the mechanical raking device. By a clever system of link and lever motion the rakes travel upwardly along the inclined plane, are lifted at right angles to the plane, carried back parallel to the plane and lowered again at right angles. The length of travel of the rakes is always in excess of the spacing of the adjacent rakes, so that each revolution advances the settled particles to a point where a new rake pushes them further upward. The angle of inclination, the speed of travel, size, etc., depend upon the material in hand, dilution of the material, the amount of back wash required, the size of the settled particles, their specific gravity, the capacity required, etc.

The fundamental success of this machine lies in the fact that all drives of the moving parts are situated above the liquor so that lubrication is secured and wear minimized.

Operation.—The operation of the classifier consists in setting the control valves and starting up the driving mechanism. Being an automatic machine there is no manual work necessary, periodic inspection of the work and lubrication of driving parts being the operator's job.

The valves proportioning the amount of feed and back wash liquor must be set to obtain the results desired. If the solution changes, best efficiency requires a corresponding change in the setting of the valves.

Advantages.—As compared with old type "fill and draw" methods of classification, or with the launder system of classification, the Dorr Classifier is a great economizer. Being automatic, no labor worth mentioning is entailed, being operated at slow speed the power consumption is trivial and, due to its maintaining a constant settling depth, it requires a minimum of floor space.

Probably the greatest advantage is its constancy of product. So long as the material coming to the machine runs uniform, positive output is assured. With older methods the resultant product depends upon the diligence and vigilance of the operator. If he overflows his tanks too quickly, coarse material is found in the fines. If he slows up the overflow too much fines are carried out with the coarse.

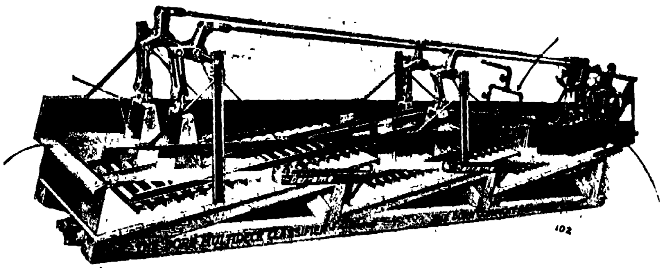
The simplicity of design and operation, the ruggedness of its construction, its flexibility to meet varying conditions in the many materials to which it is applicable, and its comparatively small cost of installation are advantages distinctly in its favor.

Drawbacks.—The force doing the actual work of separating coarse from fine is gravity. Depending upon the size of particle, specific gravity of both particle and liquor, the classification is rapid or slow. A much smaller unit would many times be sufficient were the force of gravity increased or augmented. This drawback is inherent but to date no means, including centrifugation, has been developed to effect a device that may be called a competitor.

Each machine is designed for a specific material and is good for a certain overload capacity. Temporary excess overloads are not practical with this machine as is possible by damming up launders with more frequent hosing down and cleaning. The needs of such overloads are

not and should not be frequently found although some instances have occurred.

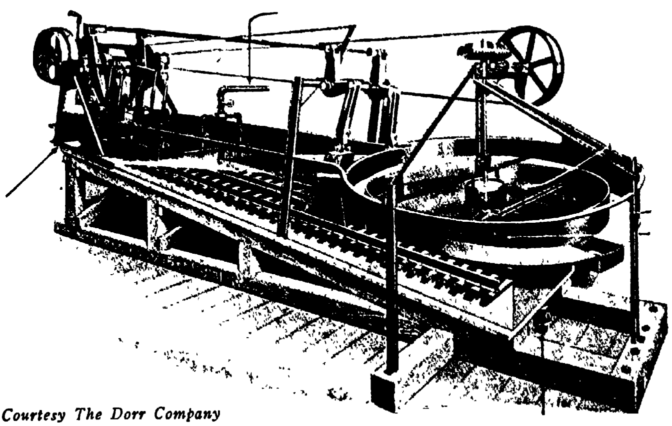
Applications.—The Dorr Classifier is the one industrial machine that



Courtesy The Dorr Company

FIG. 99.—Dorr Multi-Deck Classifier—Continuous Counter Current Washing Design.

Where the settlings must be washed free of soluble and unattainable in one long classifier, multiple classifiers are employed, the wash water advancing as a constantly enriched liquor, the solids being washed in steps.



Courtesy The Dorr Company

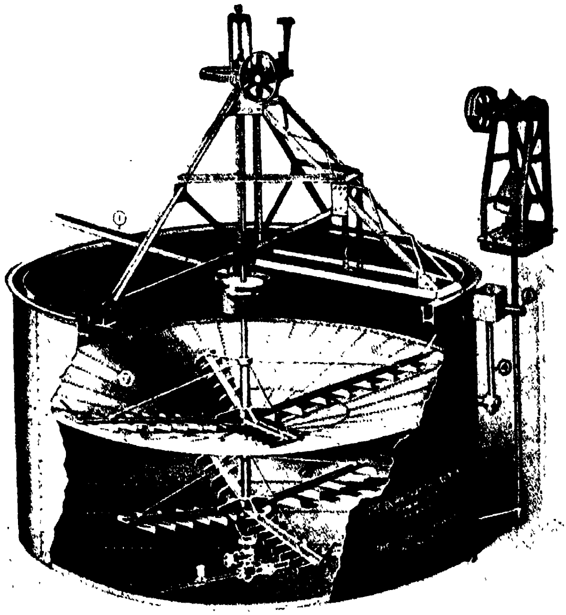
FIG. 100.—Dorr Bowl Classifier.

Where an exact separation of fine from coarse particles is required, the bowl classifier is the best classifying machine. The underflow from the bowl, which is in essence a thickener, is washed by the up flow of supernatant liquor in the classifier proper, greatly aiding thereby the washing of the fines entrained with the coarse material.

will partially clarify any liquor. Where only a part of the material in suspension is to be separated this is the machine to be used. The only requirement is that the product to be recovered from the liquor shall

have a different specific gravity or size from that to remain in suspension.

The Classifier is essentially applicable to handling coarse material, which is more conveniently conveyed than pumped and which by draining on an inclined plane will be sufficiently dewatered for any subsequent process or disposal. In this regard it differs from the Dorr Thickener which handles finer solids.



Courtesy The Dorr Company

Fig. 101.—Dorr Tray Thickener.

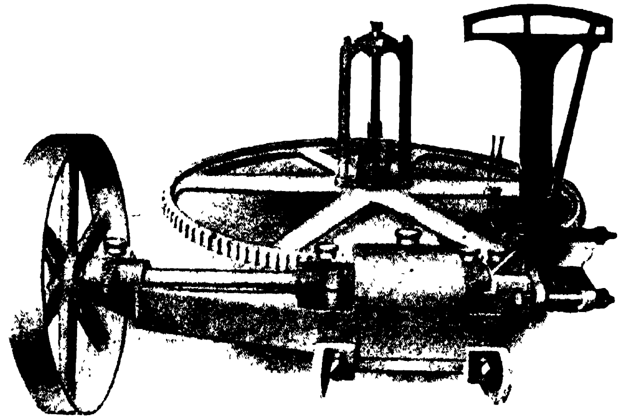
In a standard thickener of a depth formerly considered necessary a tray can often be inserted halfway down and a second series of plows fixed to the one shaft so that the settled area is doubled. The agglomerated solids from the upper fall, with negligible dispersion, to the main underflow outlet and exhaust along with the discharge from the lower settler by means of the one Dorrco Pump.

In consequence, wherever coarse particles of suspension are to be extracted the Classifier is applicable as, for instance, in separating sand from slimes, coarse coal from pulverized, oversized particles from wet grinding mills, quick settling crystals, sand from kaolin, etc., etc.

Where one Classifier will not deliver a sufficiently cleaned product or where additional wash is required series treatment with the Dorr Multi-

Deck Classifier is applicable. Where the settled product is itself a comparatively fine material, or where a more exact separation of coarse from fines is required, the Bowl Classifier, which is a diminutive Dorr Thickener combined with a Classifier, is best applicable.

Dorr Thickeners.—When analyzing the difficulties of dewatering cyanide slimes and to more easily handle the overflow from his classifier, Dorr became interested in decantation methods. There had to be a solution to just one problem, handling the settlings, and a continuous settling machine was obtained. Proof of the thoroughness of his investigation and his mechanical genius is the Dorr Thickener which so simply rakes the settled solids to a central discharge opening.



Courtesy The Dorr Company

FIG. 102.—Dorr Thickener—Overload Alarm.

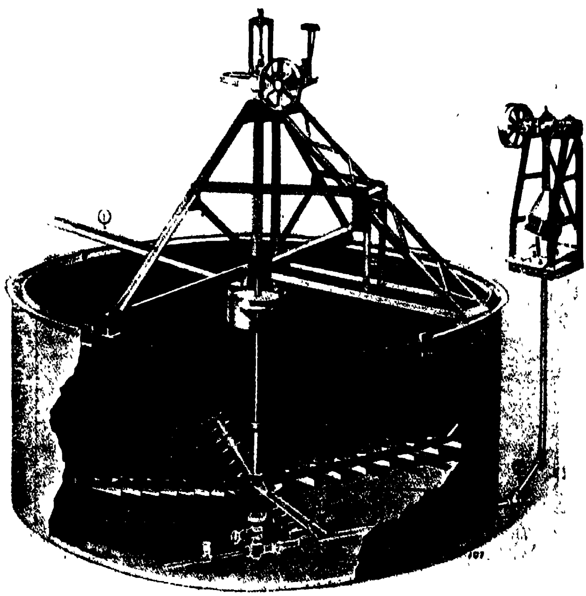
An indicating device arranged to give warning electrically of increasing power consumption, is a fool-proof device, designed to prevent excessive overloads and of real value when starting up new installations. An increase in power required to rotate the rakes increases the thrust of the worm, a slight movement of which is multiplied by the indicator.

Design.—In its simplest terms the Dorr Thickener is a continuous settling machine delivering a clear overflow and thickened solids as an underflow. It consists of a circular tank in which is located a slow moving mechanism of a central vertical shaft terminating in radial arms carrying plow blades which through the rotation of the shaft propel the settled material to a discharge opening at the center of the tank. The material to be clarified is fed to the center of the tank and the clear liquid caught in the peripheral launder.

The design of the plow blades is the keynote to the success of this machine. The pitch of the blades is largely a function of the material in hand. The design is based on the idea that, for a given rotary speed, the revolving plows shall not stir up the settled material more than to pro-

vide a gentle agitation, which has been demonstrated of distinct value in obtaining thickest possible discharge.

Practical success of the machine is founded on the ingenious idea of raising the raking arms when the machine is stopped or when the load becomes excessive. Here is the fool-proof provision in this device. As we recount the rise and decline of our industrial machinery progress



Courtesy The Dorr Company

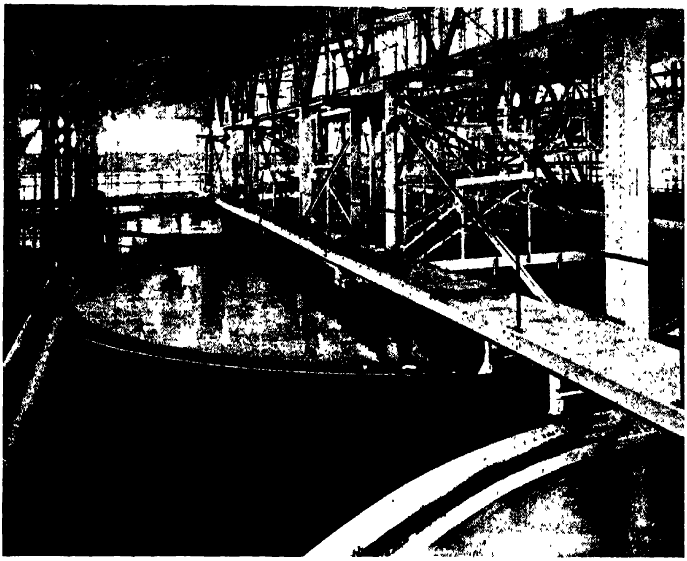
FIG. 103.—Dorr Thickener—Rakes Lifted.

When the power increases to an overload the rakes are lifted to a higher position. This is effected by operating the lifting mechanism which raises the shaft collar, to which are attached tie rods extending to the outer part of the rake arms.

those machines that have maintained success are founded on sound principles well protected with fool-proof provisions. In the Dorr Thickener the actual raising of the arms is rarely automatic but the driving mechanism is equipped with a signalling device that warns of increased power required for rotating the plows. The operator has simply to turn a wheel handle geared into a low pitch screw thread on the central shaft. As this shaft is raised a collar, to which tie rods from the arms are attached, is also raised and the arms in turn lifted to a zone of less resistance. In

this way the overload power can be maintained within the limits of the driving mechanism and operation maintained without mechanical breakdown.

The design of the tanks vary with the requirements of the material as to settling characteristics, capacity, thickness of discharge, etc. The basic feature is that there shall be sufficient settling area and depth to give required clarity of overflow and density of underflow. The continuous exhaustion of the settlings maintains the settling depth so that shallower tanks are practical than in intermittent decantation. This fact



Courtesy The Dorr Company

FIG. 104.—Dorr Tray Thickener.

A battery of tray thickeners will handle an immense quantity of liquid as found, for instance, in dewatering copper concentrates in a metallurgical mill.

has made possible the utilization of spare head room by racking one thickener over another to form multi-deck thickeners. This enables the multiplication of settling area without increasing the floor area.

When excessively large tanks are required, the drive of the mechanism is at the periphery instead of at the center. This type of drive reduces the torque that would be developed were the drive central on the thickeners 150 to 200 feet in diameter.

The simplicity of this machine makes it admirably adapted for acid proofing and applicable for acid liquors. Wood or lead lined tanks are practical. Bronze, lead covered, or wood arms and plows are likewise

good design and hence all parts in contact with the liquor can be made resistant to the material in hand.

The thickeners can be insulated on the sides and hooded over on the top so that temperatures of the liquor can be maintained when handling hot materials.

The Tray Thickener is a modification of the single compartment or unit type thickener by which increased capacity is obtained per square foot of floor space. Briefly, the Tray Thickener is the standard unit thickener of increased depth, divided into two or more settling compartments by means of trays or diaphragms. Extra sets of plow blades sweep each tray and extra outlets carry off the clarified liquid from each compartment. Separate discharge of the accumulated solids can also be provided, and even separate inlets, thus allowing the one mechanism to handle different products.

The variations in details of design are numerous to take care of the many variations required in meeting the individual conditions of the many applications to which the Dorr Thickener has been eminently successful.

Operation.—The unclarified feed should be run at low velocity, to a partially submerged well at the center of the thickener, so that there is a minimum disturbance due to currents. The feed should not contain solids that will give trouble in clogging the underflow pipe or the diaphragm pump controlling the sludge.

The quality of the overflow can be regulated in an installed thickener by regulating the quantity fed. In many uses the overflow is not necessarily a brilliant liquor and consequently the feed can be faster than were brilliant supernatant liquor necessary.

In order to maintain a constant settling depth there must be a constant withdrawal of the settlings. On the other hand, if a constant density of underflow is to be maintained the withdrawal volume must not be in excess of the volume of the settled sludge. There is therefore a critical speed of the shaft operating the Dorrco diaphragm pump. When once set this does not need adjustment save for variations in the amount of solids in the feed or in the quantity of liquor fed, or changing the stroke on the pump.

The operation being continuous, the operator's job is largely lubricating bearings, gears, etc., of moving parts, stopping and starting when working less than twenty-four hours a day, and raising the plows when warning signal indicates excessive power. In no case is this a man's full job, as the big majority of his time can be utilized on work in the immediate vicinity of the thickeners.

Advantages.—Simplicity is the chief mark of distinction of the Dorr Thickener. Design, installation, operation and maintenance are all extremely simple. Machinery progress is based on elimination of the complicated. The Dorr Thickener stands in the front rank of our chemical machinery largely by reason of the good service effected in its wide applications due to its simplicity. Engineers the world over respect the genius displayed in the rugged and simple mechanism of this machine.

Since gravity separates the solids and the liquid there is no need of

accessory equipment, the design and maintenance of which are always added complications. This advantage has a further value in the small power requirements.

Being automatic and fool-proof the operating labor expense and attention are confined to one man per shift as a maximum.

The capacity per unit area in a continuous machine is much greater than that obtainable in intermittent machines. First, the time for un-

Courtesy The Dorr Company

FIG. 105.—Dorr Thickener for Acid Liquors.

The simple mechanics of this machine are reflected in the ease with which it can be constructed of wood resistant to the material in hand.

loading the latter is time for decantation in the Dorr Thickener. Also, there is an increased thickening as a gentle agitation, as obtained by the movement of the plows, rearranges the solids to settle into a denser mass.

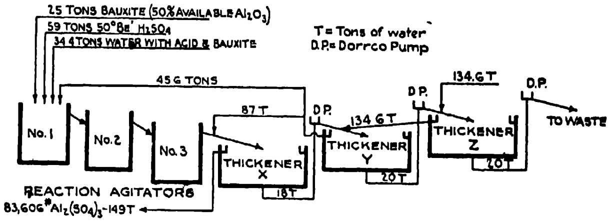
The thickener is its own storage tank. Having a constant feed, overflow and underflow there is no need of storage tank to take care of the intermittent discharge of ordinary settling tanks. Again, feed and overflow can continue for a time, even without discharging the settlings. Raising the rakes allows the solids to accumulate without overloading the drive. When ready to unload, the rakes are again dropped. The solids are, therefore, conveniently unloaded as required.

In its relationship to filters it makes filters applicable to materials to which they could not be economically used otherwise, particularly flocculent precipitates.

In the present age when stress is laid on waste recovery, the Dorr Thickener, by making solids of suspension recoverable, has opened up the economic production of by-products from wastes.

Drawbacks.—Having no clarifying medium the separation of the solids of suspension from the liquid is not positive. Each machine is designed with a sufficient time factor to provide excess time for settling of all solids but the principle of gravity settling is not absolute, as is the superlative straining of the solids through a filter medium.

Gravity being the separating force, its action depends on the difference in specific gravity or settling characteristics of the solid and the liquid. Many attempts to intensify gravity (as for instance by centrifugal force) have not evolved machines capable of handling big tonnages. This draw-



Courtesy The Dorr Company

FIG. 106.—Continuous Counter Current Decantation.

In handling bauxite liquors as well as others to which this scheme of washing is applicable, the intermediate settled solids are repulped with weaker liquid before resettling in the next thickener.

back of a limiting working force is quite analogous to the limit of atmospheric pressure as the working force in continuous filters. In each case a limited working force is an inherent drawback not, however, of serious practical importance.

The settling area for some materials is large and the floor space required often necessitates installing the machines exterior to the process building. This large floor space means large quantities of liquor in process which is always a weakness. The Tray Thickener is one answer to this drawback.

Confining the mechanism to circular tanks means that for equivalent floor space a rectangular tank can provide approximately 25 per cent greater settling area. Any drawback on floor space is always an inherent weakness but its practical importance is limited.

Application.—Aside from straight dewatering or clarification work the application for washing the solids of entrained solubles is one of the most interesting and important problems.

Many materials have resisted efficient washing in filters, especially

plate and frame presses. In intermittent decantation the practice has been to settle the solids and draw off the supernatant liquid. The settlings are then repuddled with fresh water and again allowed to settle. Again the clear liquid is decanted. By repeating this operation sufficient times the solids finally entrain water only. This method is slow, requiring in washing aluminum hydrate for printing ink manufacture four days and nights, but it is positive and gets a washed product. Naturally the decantation ought to be practical in Dorr Thickeners. When applying the thickeners an opportunity for refinements are possible. In the first place, the washing is by dilution and the underflow discharge from a thickener is a denser product than is obtainable in draw and fill methods and, consequently, with equal quantities of diluting water the dilution is greater and the washing effect increased. In addition, by reducing the gravity in steps, less wash liquor is required since weak overflow can be used to thin down the settlings from a strong tank. This principle leads to the continuous counter current wash, where the solids advance from the strong tank to the final wash tank and the supernatant weak liquor advances from the final wash tank to the first tank. In this manner the solids are washed as in draw and fill methods, but the liquid enters as a wash water and exits as a strong liquor, obviating the need of concentrating quantities of weak liquor; in most cases being used to dissolve the valuable constituents of the raw material.

There is an impression abroad that the application of thickeners and filters involves competition between these machines. Proof is given where decantation has supplanted filters previously installed. Such instances are not evidence of competition but of faulty application of filters. A rule can be formulated to the effect that for a filtrable material filters should be applied; for contrary filtering liquors thickeners should be installed ahead of filters. A filtrable material is defined as a liquor from which clarity, good capacity, sufficient displacement wash, dewatering of cake and complete discharge can be obtained in a machine the materials of construction of which are resistant to the liquor. A contrary filtering liquor needs only to fail to meet any one of the conditions just stated. Clarity may be difficult due to colloidal solids being present in a very thin slurry. Capacity may be lacking, due to a small concentration of solids entailing a heavy duty on the filter in terms of the liquid so that the solid deposit is small. Washing may be deficient due to the low percolation of the water after a resistant cake has been deposited. Dewatering may be lacking if cake cracking is intense or if the washing arc is prolonged. Discharge is difficult if cake is thin or if some fines penetrate the surface and lodge in the filter fabric. When handling heavy caustic or acid liquors, the filter medium and wearing surfaces are difficult to maintain against corrosion, scaling, etc., and are liquors to which filters are not readily applicable.

On the other hand, the underflow of concentrated solids from a thickener is more easily handled by the filters and becomes a filtrable product. From the last thickener of a counter current washing installation the caustic or acid content of that underflow is reduced to a point where

filters are applicable. Thus, the thickener is a preliminary device to filters. Conversely, the filter, discharging a cake of lower moisture content than is practical from a thickener, is a complementary machine to a thickener. At first these two aspects would seem to be identical yet, if the thickener is obviously necessary it becomes the dominant machine and the filter is a complement. On the other hand, if the filter must be used, due to the deficiencies of the thickener underflow on the particular material, the filter is the principal machine and the thickener, a preliminary.

The occasions on which there should be any overlapping or ambiguity as to the applications of thickeners or filters are narrowing down to well defined limits. The co-operative interrelation of these two machines is well appreciated and manufacturers are realizing the combined advantages. Common sense engineering will prevent any of the needless overlapping, too often stressed in the past, and insure the best service to the industrial field in the future. Granting the constant improvement in filter apparatus, increasing its application, the economies of each individual case must be the guide in defining the machines and flow charts for the particular job.

Other Dorr Equipment.—The Dorr Company has developed other apparatus such as the Dorr Agitator, Dorrco Pump, Washer, Screen, etc., which are not pertinent to a discussion on clarification. Each of these machines is the result of overcoming some difficulty in the operation of a classifier or a thickener.

Chapter VII.

Section II—Merrill Filter.

The earliest self-discharge filter press was the Merrill Filter, long prominently known by the success attained with it in the gold cyanide mill of the Homestake Mine.

Origin.—In the early days of cyanidation, C. W. Merrill, then a prominent mining engineer, saw the need of better filter press operation. His idea was to overcome the big drawback attendant on the operation of these filters in the manual labor necessary for discharge of the cake. The well-washed cake was valueless, and so could be run to waste. In localities where the mining mills were situated these tailings could be dumped on the hillside or in any low meadow or marsh. With this in mind, he worked on the principle of sluicing the cake from the filter by locating a nozzle in each frame, the water from which would cut away the cake and let it discharge as a fluid. He conquered the mechanics involved in this work successfully and his press gained a wide reputation for this work.

Design.—Superficially, the Merrill Filter looks like a conventional plate and frame press. It differs from the customary plate and frame press by its large feed or discharge eye located in the lower corner of the plate and the rotatable pipe running through the center of the filter press.

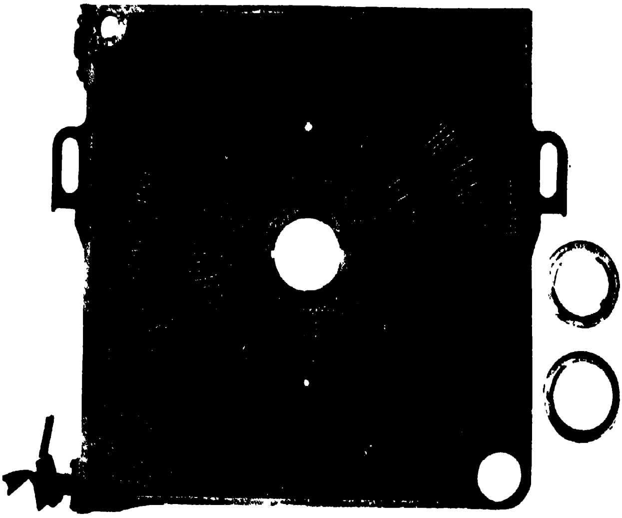
The fundamental of the design is the automatic cleaning of the cake without opening the filter. The deposited cake when disintegrated by the streams of sluicing water must be discharged from the press. The large conduit formed by the large eyes in adjacent plates provides for this discharge. It is made extra large as the sluicings drain without pressure and the area must be sufficient that the sluicings do not back up in the press.

The novel feature is the sluicing pipe. This is revolvable and extends the full length of the press at its center. The pipe carries a series of nozzles, one of which projects into each compartment. Each nozzle is drilled with two slightly divergent holes from which are thrown the sluicing streams. The sluicing water is fed to the sluicing pipe at a pressure of 50 to 75 lbs. per sq. in. so that the individual streams have a strong eroding effect. The pipe has no movement longitudinally, the deflected streams effectively sweeping across the entire surface.

The rotation of the pipe is effected by back gearing to a belt or motor drive so that the actual operation of sluicing is wholly automatic.

The drainage on the plates consists of radial grooves or ribs extending from the center of the plate. In consequence, the sluicing streams are parallel to the corrugations and the surface of the cloth more easily cleaned.

Operation.—The filtering cycle varies from the usual plate and frame practice by being shortened so that the cakes on adjacent leaves do not touch each other. Simultaneous with shutting off the feed line, the wash water line is opened and fed into the same conduit as the liquor was fed.



Courtesy The Merrill Company

Fig. 107.—Merrill Filter Press Plate.

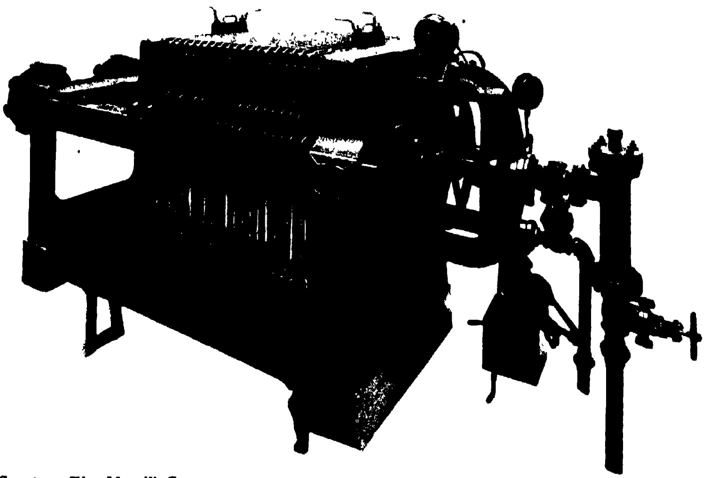
The three distinctive features of this design are (1) the large central opening through which the sluicing pipe extends; (2) the large drainage eye at the lower corner for the positive discharge of the sluicings; and (3) the radial grooving which provides corrugations parallel to the throw of the sluicing streams.

The washing, therefore, is by displacement. Care must be exercised in switching on the wash water that the cakes are not too thin or else the wash water will first act to dilute the strong liquor in the press before commencing to wash the cake. Allowing the cakes to meet is equally disastrous as then the channel for the wash water is plugged up and uneven washing results.

On cyanide slimes it was relatively easy to control the cake thickness so that the press could be charged leaving only a small space between the cakes. This space formed excellent channels for the introduction of wash water, which filtered through the cake exactly like the washing operation in leaf filters.

After the washing is completed the water pressure is turned off and the drain valve opened.

As soon as the press is drained the sluicing operation begins. The high water pressure valve is opened and the sluicing pipe set in rotation. With some materials compressed air blows out through cloths so as to aid discharge. This is continued until the water issuing from the drain runs clear. It will take from three to ten minutes depending on the nature of the material being handled.



Courtesy The Merrill Company

FIG. 108.—Merrill Sluicing Filter Press.

The marked difference between the Merrill and conventional filter presses is the rotatable sluicing pipe. This can be motor driven (through back gearing) or the motor can be replaced by a driven pulley. The filter is cleaned without opening, thereby saving labor, time, and wear on the filter cloth.

Layout.—The novelty of layout lies wholly in providing for the drain of the sluicings from the press. Where water is scarce the sluicings drop into a large settling tank and the supernatant liquor used over for the next discharge. Enough room must be provided at the end for taking out the pipe when relaying filter cloth.

Advantages.—Discharging the cake without opening the press is a marked saving over the hand labor methods of discharging ordinary plate and frame presses. Besides the saving of labor it is quicker and the filter cloth is undisturbed so that leakages do not occur and the filter cloth is not subjected to the hard wear between the gasket surfaces.

The filter surfaces are rigid and parallel and each square inch effectively swept by the sluicing streams.

The sluicing streams are of short length so that the eroding effect is ample even at the corners of the frames.

The time of discharge being short, thinner cakes and therefore narrower frames can be used so that the filtering cycle can conform to the characteristics of the material in hand. Also the time saved in discharging is more time for filtering and the capacity per square foot is increased.

Drawbacks.—Having to stop filtration before the frames are packed requires a nicety of control that limits the application of this filter to expert operators.

Discharging the solids as a fluid slurry confines the press to solids that are waste products.

The lack of accessibility to the filter cloth is troublesome whenever corrosive liquors are handled.

Being intermittent its operating efficiency is in direct proportion to the personal efficiency of the operator.

Applications.—The Merrill filter is applicable to those liquors in which the solids are run to waste and where the cake built up is easily formed of uniform thickness throughout the press. The cyanide industry was its greatest field although it is still a good clarifying filter for sugar refinery and similar liquors.

Summary.—The Merrill filter lost its popularity when the demand for dry discharge filters became far greater than for sluicing discharge. This demand incited the Atkins Brothers to develop the Atkins-Shriver Press, manufactured by T. Shriver & Company described next.

Chapter VII.

Section III—Atkins-Shriver Filter Press.

The only self-discharge filter press had been for many years the Merrill sluicing press. The Atkins-Shriver is the pioneer of self-discharge presses that recover the solid as a dry product.

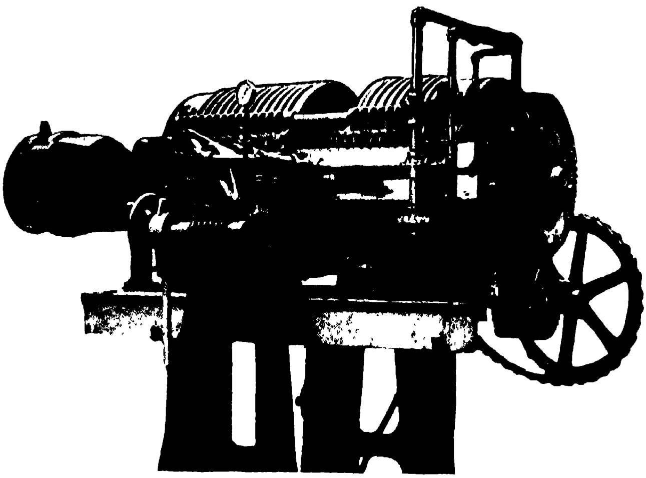
Origin.—The Atkins brothers set out to develop a continuous settling machine for their father who had a proposition of separating colloidal gold and silt and sand. Gravity would pull down the heavy particles, but this acted very slowly on the light particles. They endeavored to make centrifugal force effect a quicker separation. It was soon found, however, that the fines would separate only after being agglomerated when their bulk increased the differential of their mass weight and the liquor in which they were suspended. A machine that seemed to solve the difficulty was of small capacity and the design did not warrant building large units. Reaching a termination in this line of attack they turned to the idea of a mechanical means of discharging the cake from circular filter discs. Their success in plowing the cake from this type of machine led them to adapt it to the familiar plate and frame presses. This interested the well known Shriver Company with which a combination resulting in the Atkins-Shriver Filter Press was formed.

Design.—The filter press itself is the familiar plate and frame machine save that the plates have a large annular opening in the center. This opening must be large enough to accommodate the plows mounted on the shaft; first, for assembling plows in the press; and second, to enable the plows to be out of the cake-forming zone during filtration; and third, this opening is the discharge port and must allow the cake to fall out freely. The assembled press is mounted on trunnions so that filtration takes place with the press horizontal and discharges when the press is turned to a vertical position. The press is equipped with the usual open or closed delivery of filtrate, but has a compressed air or steam port to blow out the cloths to assist discharging whenever tenacious cakes are formed that do not readily cleave away from the cloth.

The keynote of the design lies in the plowing mechanism. The fundamental idea is to rotate one plow in each frame cutting a small amount of cake with each revolution. The plows are shaped so that the cake cut away works toward the center and falls down the annular opening through the discharge gate to any convenient receptacle. The rotary feeding of the plows is an ingenious mechanical gearing arrangement effecting true planetary motion. As the shaft moves in its orbit, the plows slowly

rotate on the shaft so that the combined rotation includes translation. The plows start from their initial position, in which their entire length lies within or across the annular opening at the center, and progress to their final position when they sweep the filtering surfaces just missing the filter cloth. The final and initial positions are fixed by stops so that the entire operation is automatic.

Operation.—Filtration to the close of the cake building period is like that of the ordinary plate and frame press. The washing operation is different being similar to that in the Merrill filter press.



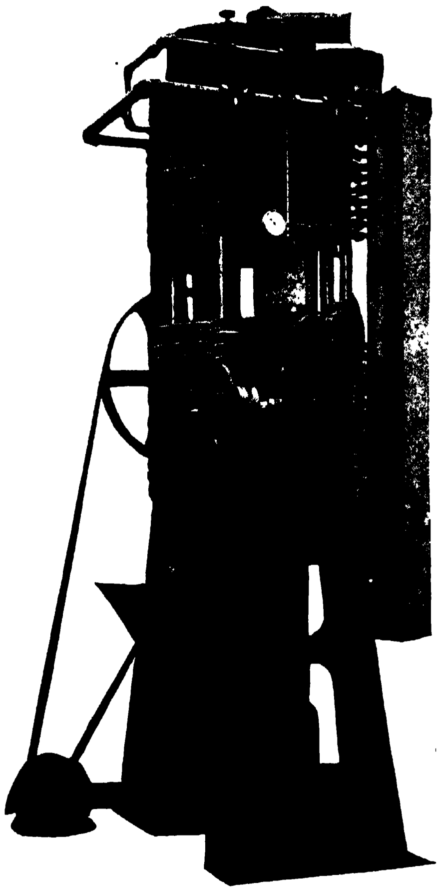
Courtesy H. D. Atkins

FIG. 109.—Atkins-Shriver Filter Press.

This self-discharging plate and frame press operates in a horizontal plane with the plates vertical. It is cleaned without opening up the plates and frames by swinging the machine to the vertical position.

If the excess unfiltered liquor is to be drained before washing, compressed air must be admitted to hold positive pressure in the press. In most instances where this press is applicable, the excess can be driven through the cake and need not be drained. It is possible to wash through alternate plates, as in the conventional filter press operation, but better results are obtained by the displacement method. When washing is completed, the usual compressed air or steam treatment for drying takes place and the cake is then ready to be discharged. After releasing the internal pressure the discharge gate is opened and the press turned into a vertical position. Power is applied and the shaft moves in its orbit within the discharge hole in the plates. As the shaft moves it is partially turned. This latter rotation governing the bite of the plows in the cake is con-

trolled by a friction pulley so that excessive power is never required to cut away the cake. A soft cake is automatically eaten into quicker than a hard resistant cake, but the action in either case takes power well within the design of the mechanism. The plows cut through the cake leaving a thin layer on the filter cloth. When the latter must be removed



Courtesy H. D. Atkins

FIG. 110.—Atkins-Shriver Filter Press—Discharging Position.

The cake is plowed out of the frames into an annular opening at the center of the press so that it can fall vertically to a hopper or conveyor, as the case may be, underneath. The gravity fall requires the press to be rotated to a vertical position, which is accomplished by rotating the trunions on which the filter is supported.

a mild compressed air or steam pressure is fed behind the cloths ballooning and raising the cloth so that the scrapers remove all of the cake. This back pressure must be small or else the cutting action of the plows may be severe upon the cloth.

Layout.—The press must be mounted high enough so that when turned into the vertical the discharged cake falls into the discharge hopper or conveyor. Much of the flexible connections formerly necessary are now

Courtesy H. D. Atkins

FIG. 111.—Atkins-Shriver Filter Press—Plant Installation.

The striking feature of this layout is mounting the filter high off the floor In this particular instance hot oils are handled at high pressures, thus requiring a plate and frame press. Automatic discharge saves the operators from arduous labor.

obviated by piping through the hollow trunnions which form the axis of rotation. The discharge can be effected in from three to five minutes unless longer reverse current percolation is required.

Advantages.—Every advantage of discharging a press without opening, as found in the Merrill filter, is obtained in the Atkins-Shriver save that in addition the cake is recovered in a dry state. Being a plate and frame press, high pressures and temperatures can be used and the final product is drier than is practical to obtain with hand operated presses or with modern filters.

Drawbacks.—The filter is circular in shape and each plate has a large annular opening, so that the filter area per unit floor space is smaller than with hand operated square presses. Greater head room is required in order to accommodate turning the press, often requiring a new location when substituting it for existing plate and frame presses. The operation is intermittent and the efficiency depends upon the skill of the operator.

Applications.—Free filtering solids requiring dry discharge represent the class of materials to which this filter is most applicable. Broadly speaking, it is applicable to all materials handled by plate and frame presses but acid liquors must be excepted as well as those materials in which the labor of discharging the standard press is small, due to size of machine or to infrequent opening. It is, however, excellent in handling liquors at high temperature and at high pressure. The latter include volatile liquors in which the press must be open to air for only the shortest possible time.

Summary.—The plate and frame press has been for so long an established filter that it is unique that the Atkins-Shriver should be the first of them to effect automatic discharge of dry cakes. The Merrill filter was the first automatic discharge plate and frame press but this differs from the Atkins-Shriver in that the cake is sluiced out. How far the Atkins-Shriver will be developed is an interesting race between the manufacturers and the increased application of continuous and leaf type filters.

Chapter VII.

Section IV—Burt Filter.

The Burt Filter was one of the earliest of self-discharge filters. The individuality of its design and its excellent performance made it well known in the early years of this century.

History.—American filtration indeed owes much to the introduction of cyanidation for gold and silver ores. Moore, Oliver, Sweetland, Kelly, Merrill and now Burt all developed their respective filters by the force of necessity in overcoming obstacles encountered in handling cyanide slimes.

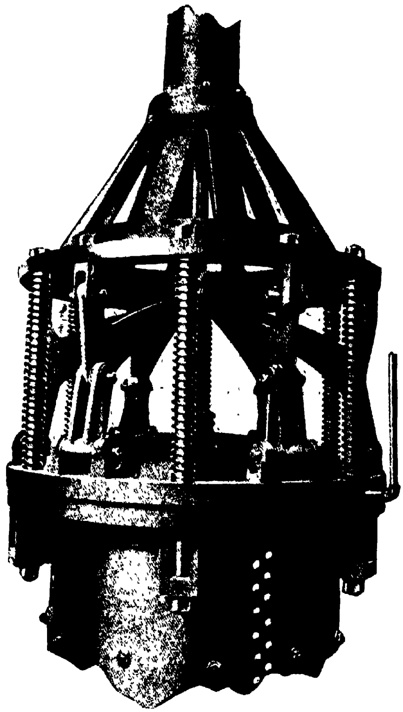
The slimes which baffled Sweetland, Oliver and the others, did not happen to be the same as Burt encountered. He had a material much more granular, so that any vertical filter medium was impractical, due to the thicker cake always building at the bottom of the filter cloth. To overcome uneven cake formation, he developed the rotary pressure drum filter bearing his name. This machine is not a continuous filter, and while it can handle large volumes of cake, it has small filter area per unit floor space and, consequently, is limited to the more freely filtering materials. When handling those materials truly applicable to it, the Burt filter is capable of a high efficiency and has a specific field to-day in handling hot concentrated free-filtering materials as sodium nitrate liquor in Chile. It is, therefore, a machine that, while not well known, is still applicable to-day and could be made a very live proposition.

Design.—This filter is a steel drum rotatable on a hollow trunnion through which the material to be filtered and the wash water are fed to the filter. The interior of the drum is lined with panels of drainage members over which a filter cloth is laid and sealed at the edges. Outlet holes are drilled in the drum at the center of each panel. An external stationary launder often surrounds the drum on the line of these filtrate outlets, which directs the filtrate into the receiving trough located under the filter.

The end of the drum away from the inlet trunnion terminates in a cast iron door cleverly designed for quick opening to allow the discharge of the finished solids. The door is held to the shell by longitudinal bolts to which are attached toggle arms, one link in each connecting to a collar on the piston rod of a hydraulic cylinder. The latter is held rigid to the longitudinal bolts by means of a rigid cone of cast iron.

The simple movement of the hydraulic piston pulls down the toggle and draws the discharge door back. Upon releasing the pressure on the

hydraulic cylinder, springs on the arms move the discharge door to the closed position and the reverse motion of the hydraulic piston locks the door tight by resetting the toggles. The take-up for compression of the gasket is obtained by moving up the collar, to which the links are attached, on the piston rod.



Courtesy Chalmers & Williams, Inc.

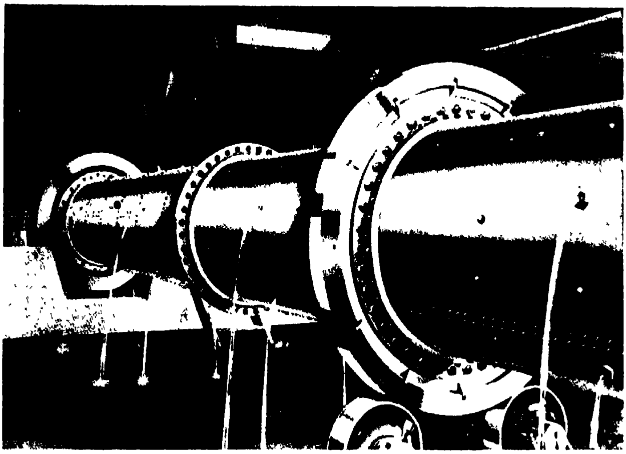
FIG. 112.—Burt Revolving Filter—Locking Mechanism.

The toggle arrangement for compressing the gasket and locking the filter is cleverly designed. The springs which serve to thrust back the head from open position are sturdy and durable for duty in chemical plant work.

Discharging the cake (which in this machine must be of a character to quickly fall from the filter cloth), is obtained by the faster rotation of the drum. On the inside, angle-irons, set spirally, serve both to hold the panels or mats in place and to scroll the cake from the drum to the opened end of the machine. The solids must be moist enough to roll out without dusting and will often require a slight rewetting.

Operation.—The operation starts with the filter revolving, when the inlet valve is opened, admitting the material to be filtered. As the liquor

enters, the air is forced out through the exposed filter cloth. As soon as the liquor level rises so that positive pressure is obtained, filtration commences and cake starts to form. The heavy material in the slurry drops to the bottom of the drum and becomes part of the cake at that point but as the drum revolves, new cake forms at the bottom and more of the sediment is deposited. In this manner, therefore, a uniform cake is obtained, irrespective of any natural classification of the material. It will be noted that no agitation is required in this machine.



Courtesy Chalmers & Williams, Inc.

Fig. 113.—Burt Revolving Filter—Delivery of Filtrate.

The rotating cylinder is an apt reminder of cylindrical kilns, but the open delivery of the filtrate through the casing quickly designates this as a filter. The simplicity and strength of construction, both of the machine and the filtrate well below it, are distinctive of the Burt Filter.

Filtration continues until the resistance of the cake makes advisable switching over to the washing operation.

The first step is to close the feed valve and admit compressed air to the machine. As the pressure forces out the filtrate, the liquor level in the drum drops, and part of the cake is submerged, and the other part subjected to compressed air. *In ordinary types of filters this would be fatal,* but as the drum rotates, the exposed cake drops into the liquor and becomes thoroughly wet. Any cakes that tend to crack due to the air filtration, have the cracks sealed as the cake becomes re-submerged. It is advisable to continue the exhausting of the materials to be filtered until none of the liquid remains in the machine. The wash water is then admitted, maintaining positive pressure on the filter at all times.

The washing is generally accomplished by filling the entire opening

in the filter with wash water and continuing washing until the gravity of the wash filtrate falls to a point close to the desired limit. Wash water is then cut off, and the compressed air or steam again admitted as when exhausting the liquor after filtration. The effect of alternately wetting, and drying with compressed air, often proves a most economical means of lowering the soluble content with the minimum water.

The usual practice is to use a clean wash water for extracting the soluble from the cake. The scheme of using a muddied wash water is particularly applicable in the Burt Filter. The drying of the cake as it rotates above the wash water level can only result in a contraction of the volume of the cake, producing cracks, pit holes, or other paths of short circuit through the cake. If the wash water is clean, much of it will pass through the short circuits without doing the work of extracting the soluble. If the wash water is muddied with washed cake from a previous run, then the cracks are automatically sealed and the water penetrates the cake evenly.

After washing is completed the compressed air is shut off and the pressure in the machine reduced to zero. Recent designs call for a variation in rotative speeds. In Chile, for instance, the speed during filtration is ½ R.P.M.; during washing 7½ R.P.M., and during discharging 15 R.P.M. In consequence, with the door open the variable speed motor is thrown to high speed. The rapid rotation moves the cake more quickly and effectively discharges the cake in less than five minutes.

Layout.—The rotary feature calls for a set-up not unlike rotary cement kilns or cylindrical dryers. Besides the foundations necessary, a receiving well under the machine must be provided to collect the filtrate, and a hopper or conveyor for the cake discharged from the end of the machine must be installed.

Advantages and Drawbacks.—The simplicity of this machine is not only advantageous in its construction but also in its ease of operation.

The ability to form uniform cake irrespective of the settling qualities of the material, makes this machine unique among all pressure filters.

The alternate wetting and drying with a reduced consumption of wash water is a feature of this machine not obtained with any other type.

Open delivery of filtrate is objectionable since the liquor must always be collected at a point below the filter. This eliminates any possibility of operating the filter with a back pressure which is so advantageous in handling scale-forming and supersaturated liquors.

If the material in hand changes from a free-filtering to a relatively slow-filtering character, so that only a thin cake can be built up, the volume of the liquor to be exhausted becomes excessive and the time required prolonged.

This machine is essentially a large cake building filter, and if only thin cakes are obtainable, the capacity per square foot of floor space is too small.

If the cake after washing holds together, it will refuse to fall to the bottom and defy discharge even if the cakes be as much as 11 in. thick (as can be obtained in filtering calcium sulphate from citric, boric, or

Courtesy Chalmers & Williams, Inc.

FIG. 114.—Battery of Burt Revolving Filters.

An installation of a battery of Burt filters is the simple placing side by side of individual units. There is no twin arrangement, no overhead room, or space for counterweights to be provided. A common pipe line of high pressure water is fed to each hydraulic cylinder of the filters and operated through its own control valve.

similar acids). There is no way in the Burt filter to discharge such cakes, although a modified design could be worked out. In this design there would be a strip of dead area (inert to filtration) the full length of the drum and at least 6 in. wide, so that the cake could not form on it. This would break an otherwise continuous arch of cake. If this arch is not broken in the regular design, reversed compressed air simply jams the cake tighter and tighter. By breaking the arch, reverse compressed air can thrust the cake to the bottom of the filter where it would discharge in the regular manner.

Applications.—The Burt filter has been successfully used on granular ores in the mining industry, and has been lately tried out in the Chilean saltpetre fields and could be adapted to numerous other materials of a free-filtering nature in the chemical field, were some minor improvements made in the design of the machine.

Summary.—The Burt filter had an era of promising popularity during the early application of the cyanidation of gold ores. It has failed to keep pace with the leaf and continuous rotary filters in its application to the chemical industry. Fundamentally, this machine should be serviceable in many instances, but its development has lagged severely and retarded its application.

Chapter VII.

Section V—Zenith Rotary Hopper Dewaterer.

This filter is a series of enlarged Buchner Funnels located around the drum of a Zenith Rotary Filter. It handles crystals, granular products, and the like which cause trouble in ordinary filters due to their rapid settling.

Origin.—In an early application of Zenith filters to a slurry containing salt crystals it proved that agitation of the settled crystals became excessive, but that the material could be handled by feeding the material close to the zenith of the travel of the filter. It became difficult to set the feed so that an even cake was formed. From this was developed the idea of locating hoppers to retain the feed to each section and the refinement now known as the Rotary Hopper Dewaterer resulted.

Design.—Each hopper is supplied at its bottom with its filtering member, drainage and outlet pipe. The latter terminates in the movable hub of the conventional continuous filter valve. Each hopper is, therefore, a separate filtering unit with flaring sides so that the cake is discharged by turning it upside down.

The feed to this machine is at a point on the ascending side 30 degrees under the zenith of the travel. In consequence, the control valve opens up each compartment to vacuum pressure as it reaches this point. The mother liquor port takes all the filtrate obtained until the compartment reaches the zenith, when the wash liquor port opens and sucks out the mother liquor displaced by the wash. Suction continues until the compartment reaches the horizontal when reverse air or steam blows out and ejects the cake from the compartment. From this point around to the feed point the compartment runs blank.

When starting up the machine it must be set in rotation but when the hoppers begin discharging there is an excess load on the descending side which overbalances the load on the ascending and often requires a brake to maintain proper rotative speed.

Operation.—The feed from the overhead chute must be controlled so as to evenly load each compartment. The feed material must be fluid enough to evenly distribute itself in the hopper. Feeding too much material overloads each compartment so that the dewatering effect is lowered while to feed too little allows too great an air percolation and drops the vacuum pressure.

The rotation must be adjusted so there is time for the drying effect without excessive air intake through cracks or pit holes. The wash liquor

must be supplied at a rate so as to displace the mother liquor without dissolving any of the crystals.

So long as the solids filtered are all granular or crystalline the discharge is quite satisfactory, but if fines collect in the filter cloth the mild reversed air is ineffective in discharging them.

Courtesy Industrial Filtration Corporation

FIG. 115.—Zenith Rotary Hopper Dewaterer.

This, the first of continuous machines adapted to the dewatering of crystalline products, is a series of hoppers closely related to the familiar Buchner Funnel filter of laboratory practice, each supplied with its own outlet piping into the main control valve. The latter parallels the valve used in rotary drum filter design.

Layout.—Sufficient room underneath the machine is necessary for the removal of the dried solids. Headroom sufficient for the feed trough is required but otherwise the standard layout for rotary filters is used.

Advantages.—For coarse sandy products and crystals suspended in mother liquor this machine is a simple device for recovering the crystals in a washed and dried state without encountering the difficulties of main-

taining agitation coincident with rotary or leaf filters applied to these materials.

Being automatic and continuous its economy over gravity or suction bed filters is an obvious advantage.

Drawbacks.—Crystals so coarse as to give trouble in operation of standard rotary filters are easily handled by centrifugals which deliver a drier product than is obtainable by the working force of any vacuum pressure.

For two thirds of the rotation this machine is idle making the dead period excessive.

Its application is limited to a narrow range of products.

Summary.—This machine is a typical example of the way a special filter is developed by making changes in a standard machine to meet unusual conditions. The same difficulty in handling crystals was encountered in the Oliver filter and led to the development of the Oliver Continuous Sand Filter.

Chapter VII.

Section VI—Oliver Rotary Sand Table.

This is a continuous horizontal bed filter applicable to coarse granular materials not adaptable to Oliver filters.

Origin.—The Oliver filter has long been the popular filter to dewater the underflow from Dorr Thickeners. There was a demand for a continuous dewaterer for the tailings from Dorr Classifiers. Such materials are not fluid enough to flow to the container of the Oliver filter but are conveyable down a chute or launder. It was, therefore, in order to meet this condition that the rotatable, horizontal table filter was developed. The filter is sectionated on the same principle as underlies the multiple compartment Oliver Continuous Filter and all the flexibilities of the control valve realized. The sand table filter is thus a modified Oliver Continuous capable of handling the overflow of Dorr Classifier and crystalline solids equally troublesome for Oliver filter operation.

Design.—The striking feature of the design is the annular horizontal bed, containing filter medium, drainage member and compartment outlet pipes with flanges at the inner and outer periphery to retain the material fed to the filter. The bed is divided into sector shaped compartments, each independent of the others and communicative with the control valve through separate piping. The filter rotates in a horizontal plane so that the driving shaft and movable hub of valve are vertical and below the level of the bed. The driving mechanism is through worm and gear reduction analogous to the drive on the filter.

The discharging apparatus is novel. When the compartment reaches the point of discharge the control valve cuts off vacuum and reverses compressed air through the filter medium. A radial scraper lifts the solids from the bed and an elevator conveys the cake up an inclined plane over the side of the machine. This makes a simple but effective means of discharging the filtered material.

If solids require washing, water may be sprayed or sprinkled upon the cake just as the liquid drains leaving a dry cake. The exact location of the initial application of the water is best determined after installation is made.

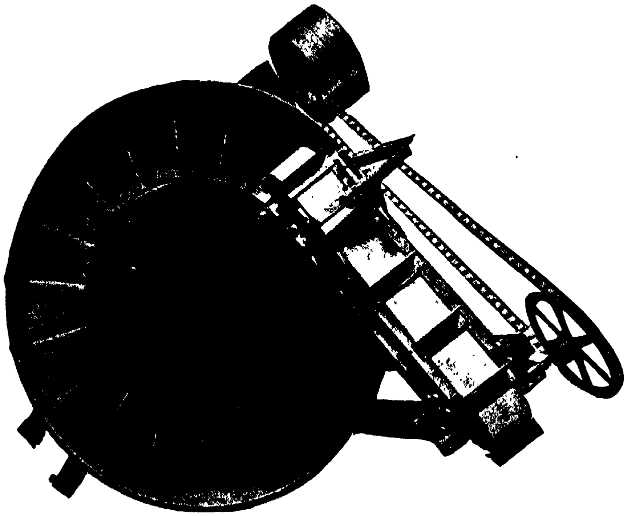
The vacuum accessory apparatus is analogous to that standard with Oliver Filters.

Operation.—The feed must be regulated so that excessive quantities of material do not fall on the freshly cleaned compartments.

With this set for a given amount with constant flow the speed of rotation is fixed to accomplish the work in hand—wash and dewater or dewater only.

The elevator is driven from the main drive and needs no adjustment as to speed.

This machine functions by reason of the high capacity obtained per square foot of filter surface and consequently the material to be handled must be free filtering. It is a mistake to feed coarse and fine material



Courtesy Oliver Continuous Filter Company

FIG. 116.—Oliver Continuous Sand Table—Aeroplane View.

The individual sector shaped compartments are supplied with individual pipes to a main control valve, similar to standard Oliver Filter valve, located below. The filter operating in a horizontal plane requires the belt conveyor to lift treated cake out of the machine.

to this type of machine unless clarity of filtrate is nonessential. Open weave metallic or fibre filter cloth is used and dense cloths sufficient to completely clarify fine materials should not be used.

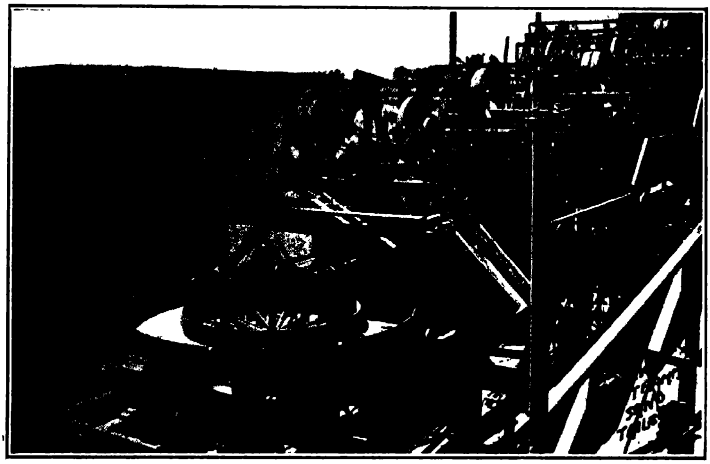
Layout.—The standard layout for this machine must include, in addition to the usual vacuum accessory equipment always required with vacuum filters, a source of constant feed such as Dorr Classifiers. In consequence, the sand table must be located in proximity to this supply.

The discharge of the dewatered material offers variations in layout capable of meeting local conditions. The material rises up a conveyor which can be carried to a point convenient to drop the material into a cross conveyor or up to a floor above the machine.

Advantages.—Dewatering of classifier discharge, crystals from chemical solutions, etc., is effected by the Oliver Sand Table with all the flexibility of an Oliver filter and with none of the troubles of maintaining agitation or of feeding to that filter.

The bed being horizontal, gravity acts to aid the suction, and the draining of the mother liquor is maximum and uniform over the entire surface of the cake.

The entire rotation is effective save for the small arc at which discharge and reloading take place.



Courtesy Oliver Continuous Filter Company

FIG. 117.—Oliver Continuous Sand Table—Dewatering Classifier Discharge. The ability to dewater materials unpumpable is a distinct application of this machine. The combination of the Dorr Classifier and Oliver Sand Filter is here handling the tailings of a mining operation in Chile.

Drawbacks.—The dewatering effect is limited to vacuum pressure, which is small compared to that obtained in centrifugal machines, and dryness is often lacking especially with viscous mother liquors.

The floor area and head room per unit filter area is excessive and warranted only by the high capacity obtained.

Applications.—Wherever the solid overflow from a classifier has to be dried the rotary sand table has an application.

Salts that have been quickly crystallized so that their particle size is small for good centrifuging and still too large for good handling in Oliver filters are dewatered by this machine.

Wet screening delivering material ½ inch to 100 mesh, deslimed ore, sand obtained in leaching sodium nitrate in the Chile saltpetre fields, etc., are typical materials adaptable to this apparatus.

Summary.—Within the limits of vacuum as a working pressure, the results with the Oliver Sand Table are very creditable.

The idea of a sand bed filter has often been suggested for acid filtration. This principle is used in the FEinc Acid Sand filter, an intermittent machine with automatic discharge, next discussed.

Chapter VII.

Section VII—FEinc Acid Filter.

This is a sand or silica-block bed filter in which the deposited solids are discharged dry without hand labor.

Origin.—After the close of the war an acid manufacturer obtained an order for clarified 98% sulphuric acid. This strength of acid is obtained by mixing oleum and 66° sulphuric acid. At this concentration the sulfates of iron and lead are thrown down as solids of suspension so finely divided as to approach the colloidal state. To clarify this liquor by decantation required thirty days settling. To filter it meant using silica carborundum, alundum, etc., as the filtering material. Efforts to obtain a block dense enough to clarify it resulted in getting a block so dense that after a few runs it became impervious.

The Filtration Engineers Incorporated were retained to work out a solution to the problem. The initial attack was to use the precoating and filter aid methods so advantageous in cane sugar liquor clarification. Clarification was quickly obtained and a commercial rate of flow obtained but there remained the question of how to discharge it. The cake was only 1/16 in. thick so that scrapers were out of the question. The answer was found in laying an iron screen on the filter surface and letting the thin cake build in the meshes of the screen so that as it was lifted from the filter the cake was stripped from the filter medium. There still remained to discharge the cake from the screen. The mesh of the screen had to be small to engage the cake but now it gripped the cake too firmly. This was solved by modifying the operation. After laying the screen on the filter fine sand was dusted over the screen so as to obscure it. Filtration then progressed as formerly. All the cake was deposited on top of the sand so that in discharging, raising the screen from the horizontal to the vertical was sufficient to let the thin cake slide off and be discharged.

With the discharge effected by such simple means the FEinc Acid Filter was designed incorporating it.

Design.—Being an acid filter the materials of construction have to be resistant to the acid being handled. In strong sulphuric, iron is practical and one design is possible; with phosphoric, lead only is resistant, here another design is practical.

In each case, however, the basis is a horizontal bed filter, with adequate drainage and support to withstand suction pressures. The filter medium may be some resistant porous block or a level sand bed.

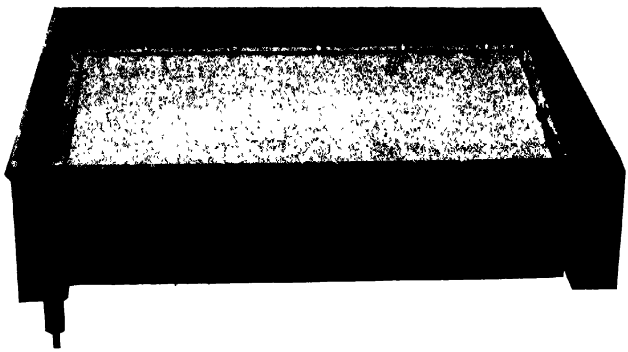
The liquor must be fed so as not to impinge upon the filter surface

or else the precoat at the point of impingement will be dislodged. In consequence, a feed trough, which also acts as a drain trough for excess unfiltered liquor, is provided the length of the filter so that the feed is evenly distributed the length of the machine.

The discharging member is hinged so as to lie flat on the bed during filtration and to be rotated clear of the filter for discharge.

Where thin cakes are obtained a sand dusting device, similar to that used in sanding tarred felt travels over the machine.

The details of design are all worked up with reference to local conditions and the material in hand.



Courtesy Filtration Engineers, Incorporated

FIG. 118.—FEinc Acid Sand Filter.

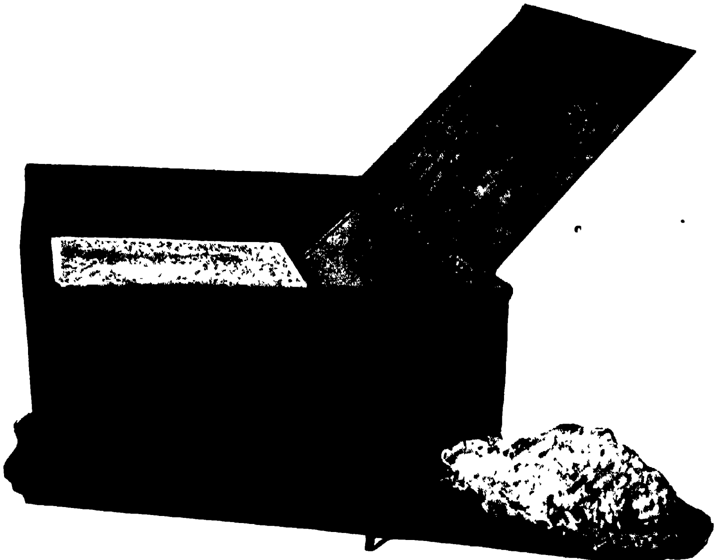
Conduits surrounding the sand bed provide the means of distributing the liquor and wash water, and to drain the excess at the close of the cycle. The cake built up on the bed enmeshes in and builds over a hinged conveying member. The entire machine is lead covered to withstand acid liquors.

Operation.—With the discharging member in position on the bed and the sand dusted over it, the initial operation is to feed the liquor into the feed trough. As soon as the liquor line is opened the vacuum line is opened and filtration progresses. When the flow falls to the economical limit of flow filtration ceases by closing the liquor inlet and opening the drain line to exhaust the excess unfiltered material. If the cake is to be washed promptly upon the finish of the draining operation the wash water is admitted to the same feed trough. This water must be muddied by the solids of a previous run, as the time element in draining the excess and feeding the wash water is sufficient to crack the cake and the solids in the wash water have for their function sealing these cracks and checking the short circuit these cracks would produce if left open. Drying is the simple filtering of atmospheric air through the deposited cake after draining the machine of liquor.

To discharge the machine the stripping member is rotated over the discharge hopper and the solids dislodged from the screen into it.

Layout.—Head room is required for rotating the discharging member and a discharge hopper must be provided at the back of the machine. This filter being of a horizontal bed type must be level so as to evenly drain. The piping varies with the material in hand and in reference to local conditions.

Advantages.—Cakes from acids are dangerous for operators when hand methods are necessary for discharging, so that a discharge requiring no hand labor is a boon to the clarification of such materials.



Courtesy Filtration Engineers, Incorporated

FIG. 119.—FEinc Acid Sand Filter—Discharging.

The simple rotation of the hinged screen strips all cake from the filter bed and discharges it into a hopper or trough located below the back end of the machine. Cakes ranging from 3/16 of an inch to 3 inches thick are readily discharged by this device.

Being able to handle thin or thick cakes makes the machine have a wide range of application.

By using muddied wash water exacting wash results can be obtained with unskilled labor.

The simplicity of design of this machine insures the construction being made of materials resistant to the acid being treated.

Drawbacks.—Being a horizontal bed machine the area per unit floor space is small unless multiple deck machines are used.

Being a vacuum machine volatilization has to be recondensed and scale forming is accelerated.

Applications.—It is practical on corrosive acids in which silica and one or more metals can be used, such as phosphoric, sulphuric, mixture of sulphuric and nitric as used in the manufacture of nitro-cellulose, etc.

Its application is confined to corrosive liquors on which continuous filters are not applicable and its field, therefore, is small.

Summary.—With this most limited filter we close Part II on Mechanics of Filters, but mention should also be made, in passing, of the Berrigan Filter and Morton Clarifier, as they fall into the class of "special filters."

The Berrigan has now been confined to materials requiring the squeezing action of low pressure hydraulic presses, such as used on juice from grape pulp, etc.

The Morton is a fine screen clarifier with automatic discharge and has some possibilities in sewage, principally as a thickener.

In addition, other special machines have been put out, such as the Sweetland Rotary Leaf, Berger's Displacement Wash Plate and Frame, etc., but their applications have been relatively few, and none of recent installation. Their practical interest is, therefore, depreciated.

Having now outlined the theory and mechanics of filtration, in order to complete the subject we logically pass on to the point of putting these principles to practice, and outline discussion of this under the head of Filter Practice.

PART III.

FILTER PRACTICE.

Chapter I.

Applications of Industrial Filters to Representative Materials.

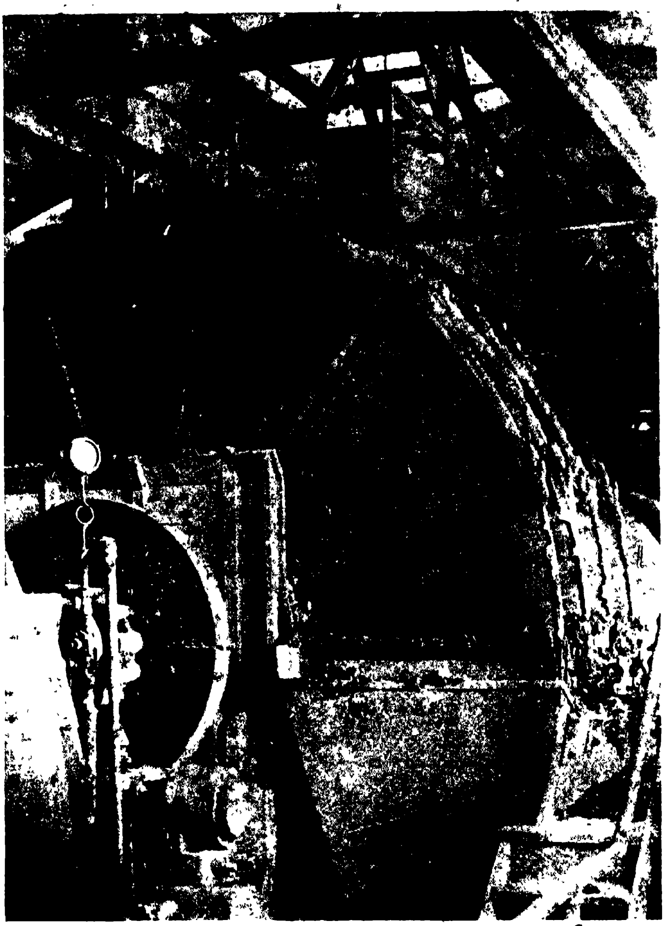
The application of any filter to any material is determined after considering the factors of cost, adaptability, efficiency, life, control and convertibility. Cost must be the first consideration, for purchase of an unnecessarily expensive filter is poor engineering. The other factors are possibly more specifically engineering and, therefore, generally viewed as primary.

The cost of a filter is not the purchase price nor the cost of machine installed. It is a per annum figure including a good charge for interest on the investment as an operating charge. It is also inclusive of a safe figure for depreciation and obsolescence as well as for major repairs and, lastly, includes cost of operation. When such costs are figured the purchase price loses the importance too often given to it. In the discussion that follows the cost is assumed favorable to the machine recommended. Local conditions will often, however, reverse this assumption.

Adaptability of a filter to any material should never be based on a single test on a material. This has been done too often in the past only to find later that the material cannot be discharged, or that corrosion is excessive; etc., etc. The machines listed for application on the various materials are actually working on the material under discussion. They are, therefore, adaptable, at least, in some plants. Many superintendents feel that their local conditions are so different and that improved machines are not applicable. Occasionally, only, is this true. Capacities, and total efficiencies, may vary in different plants but the same care of handling the material prior to filtration can be effected in every plant. Here lies the answer as to whether a machine is adaptable or not.

The factor of length of life in relation to the application of any machine is obviously vital. One is impressed by the variance in life of similar machines working on the same product in different plants. The life of any machine is directly dependent upon the care and attention given to its maintenance. It is assumed in the enumerations made later in this chapter that when handling a corrosive material customary care can be exercised. Cases where a certain type of filter was tried and later discarded because some vital part repeatedly wore out have been contrasted with similar installations still going well. The life of a machine, therefore, is a local problem aside from the corrosion on the machine.

In like fashion control necessary for daily production and converti-



Courtesy United Filters Corporation

FIG. 120.—American Continuous Filter—Discharging Ore Concentrates. The reverse compressed air blows off cakes of this character so that the scraper is quite auxiliary to the discharging operation. The efficiency of the drying cycle is denoted by air cracks occurring uniformly in the cake prior to discharging.

bility to other products enter in as local considerations when determining the application of a machine. Especially is this true when two or more types can be used. It should, however, be remembered that in starting up a new process, the simplest machine should be the first used. Refinement of process can well afford to follow initial production.

In the matter of applying filters to specific duty, the American manufacturers have earned an enviable reputation. Never has a case been recorded of anyone wilfully selling a man a machine that was known to be inapplicable for the work required of it. Many, many cases are recorded of manufacturers refusing to sell filters for a duty that might reflect badly on them. There are too many fine big fields needing better filtration for any one machine or manufacturer to attempt to cover them all. One order is never a serious loss and, consequently, every operator can be assured of honest counsel from the manufacturer. Ambiguity is a needless hazard. Secrecy is practical; it has only to be asked of a manufacturer to be conscientiously kept. But every filter man begs for complete details and failure here has accounted for the large majority of filter applications misapplied.

In the following list of representative materials, the filters best adapted to each are noted.

Acids.

Acetic.—When obtained as pyroligneous acid from distillation of wood, requirements are clarification and washing acid from solids of suspension. Acid content is low enough for pressure leaf filters to be applicable. Volatilization of acid detracts from use of vacuum leaf and continuous filters. Many plants are small and plate and frame presses are best.

When obtained from treating calcium acetate with sulphuric acid, plate and frame presses are best. The higher strength of acid requires aluminum construction for pressure leaf filters.

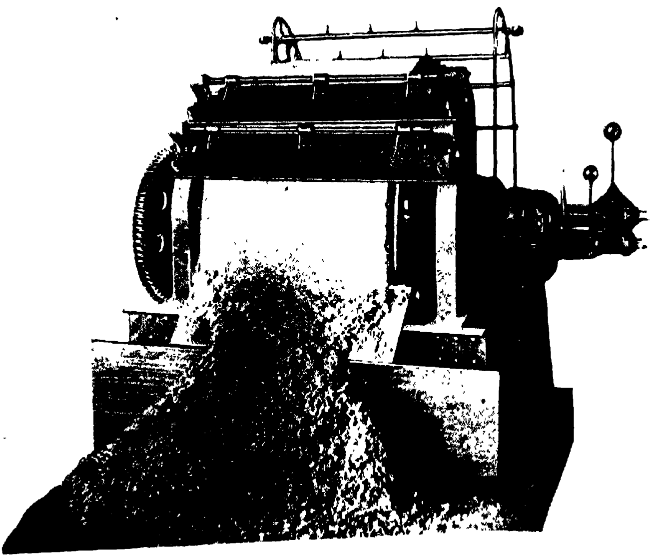
Boric.—As handled on treating calcium borate with sulphuric acid, wooden plate and frame presses are best. The liquor is hot and the excess sulphuric acid present makes the liquor corrosive to every available material of construction except wood and lead. The rapidity of crystallization of the super-concentrated boric acid prevents vacuum filters being applied, as the crystal is kept in solution by high temperature and pressures above atmospheric. Lead lined pressure leaf filters are not practical machines mechanically on this material.

Citric.—Chemically pure acid requires high purity of the calcium citrate before acidulating with sulphuric acid. It is standard practice to wash the citrate free of soluble salts. This is nicely accomplished in a series of continuous filters so constructed that iron cannot contaminate the solids. Lead lined pressure leaf machines do good work on this material as the temperature of the slurry is not high and creepage of lead lining immaterial.

Acidulating the citrate is carried on at an elevated temperature. The calcium sulphate resulting is easily filtered but requires washing. Continuous filters designed to withstand the corrosion of the excess sulphuric acid are better than lead lined pressure leaf machines, the mechanical upkeep on the latter being heavy. Acid proof vacuum leaf filters are

practical mechanically but the cake, being very free filtering, builds up heavily and is hard to transport from the filter tank to the washing tank.

Lactic.—Requirements for this commercially pure acid make the process quite similar to the manufacture of citric acid. Its corrosive power is not so severe, however, and copper is a practical metal of construction. Leaf filters, pressure or vacuum, handle this material, and wash the cake very well. Continuous filters should be applicable especially



Courtesy Industrial Filtration Corporation

FIG. 121.—Zenith Filter—Discharging Calcium Sulphate.

For a free filtering material, machines of low submergence give greater arcs for washing and dewatering the cake. With some hard surfaced cakes it is quite practical to iron the surface of the cakes with "pressure shoes."

if series operation were practiced. For small capacity output, plate and frame presses are best.

Oxalic.—The characteristics of this liquor when the calcium salt is acidulated with sulphuric acid is practically identical with the above but pressure machines are better than vacuum filters, if the acid is at all strong.

Phosphoric.—Whether bone-char or phosphate rock is the base, the resulting phosphoric acid is corrosive to a point that defies filtration in anything other than wooden plate and frame presses. Modern practice is to handle the strong liquor first in Dorr apparatus, and to filter and

wash the solids delivered from the last Dorr Thickener on a continuous filter.

Tartaric.—Characteristics of this acid are identical with those of citric acid.

Salts, Etc.

Aluminum Hydrate.—When this is used as the base of lake colors it is necessary to have the best possible washing to eliminate soluble salts such as chlorides and sulphates. Pressure leaf filters are most successful on it.

When this is obtained preliminary to the manufacture of metallic aluminum, or iron free alum, it is an easily filtered product. Continuous filters are best, if protected against caustic corrosion. Pressure leaf filters have long been used but continuous decantation handles the heaviest liquor with least replacement expense.

Alum or Aluminum Sulphate.—Clarifying this liquor free of silicic acid offers a problem in filter cloth design that has never been solved. It is necessary to settle the strong liquor and weaken the thickened slurry before filtration is practical. The slow filtering rate has to date demanded the use of plate and frame presses as the machine most popularly applied. Some plants have succeeded in operating pressure leaf filters on mud washed way down.

Anthracene.—When the crystals are very small, as obtained by quick chilling under agitation, ordinary centrifugals are impractical. Continuous filters will make sufficient oil separation that the discharged solids can be centrifugated and economically purged of excess oil.

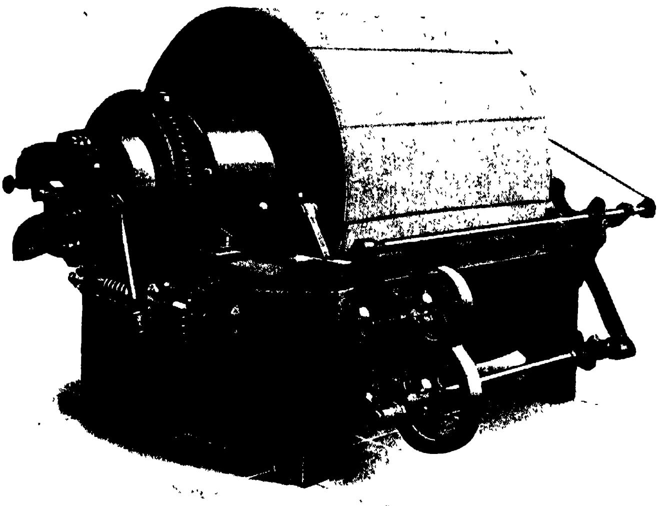
Antimony Sulphide.—This product, as the penta-sulphide, is accompanied with free hydrogen sulphide, so that the product must be handled in machines withstanding the corrosiveness of this material. The cake requires exacting wash so that pressure leaf filters have been a big success here.

Barium Carbonate.—The filtering characteristics of this compound is generally very slow and, in consequence, plate and frame presses are preferred.

Barium Sulphate.—When this is found in combination with another salt it is more easily filtered than is generally the case when precipitated alone. Lithopone, or barium sulphate combined with zinc sulphide, is satisfactorily handled on continuous filters if the liquor is concentrated and heated. Plate and frame presses have long been the customary, and still are the safe means of handling this material.

Calcium Carbonate.—This material is handled more often than any other single chemical. It is relatively free filtering so that continuous and pressure leaf filters generally are applicable. The capacities obtainable vary through wide limits depending upon the methods by which it is pro-

duced. This holds true when manufacturing the same final product as in the beet sugar industry, caustic soda, borax, etc. When there are possibilities of calcium bicarbonate being present vacuum machines are impractical. When precipitated in heavy caustic solutions metallic or other noncorrosive filter cloth is necessary. Some plants prefer Dorr counter-current washing system for strong liquors and dewater the final residue with continuous filters covered with cotton fabrics.



Courtesy Oliver Continuous Filter Company

FIG. 122.—Oliver Continuous Filter—Modern Design.

Closed end drums reduce excess unfiltered liquor, oscillating arm agitators prevent settling, the sturdy hub, bearing, worm and gear, and valve insure long maintenance, while safeguarding gears eliminate accidents, the whole combining to make a well-designed and constructed machine.

Copper Carbonate.—This material filters very readily but, unless compressed, cracks badly on air drying. The latter difficulty has resulted in plate and frame presses being standard for this product.

Edible Oils.—Whether the origin is seed, nut, fish or animal fats, a preliminary clarification is always desirable. Footz in cotton seed, peanut, etc., oils, scrap in fish oils and foreign matter in lard oils are all hard to filter. Until consideration was given to the principle of filter aids these materials were best settled rather than filtered. If properly fortified with free filtering material they are easily filtered but safety first calls for plate and frame presses. Pressure leaf machines have been installed and continue to operate but they are poorly applied.

Decolorizing these oils by mixing in fuller's earth requires clarifying

the oils free of the earth. Nothing has to-day supplanted plate and frame presses which are easily the surest in everyday operation. Pressure leaf machines do not deliver the dried cake obtainable from plate and frame machines and cannot be considered applicable for this work.

Ferric Hydroxide.—This material is very flocculent and, as such, is very difficult to filter. Plate and frame presses are the preferred machines unless by decantation the solids are concentrated so that continuous filters can be applied.

Ferric Ferrocyanide (Prussian Blue).—The fineness of particle size of this material demands long filtering cycles in order to get any appreciable cake. The subsequent operation of drying is an additional reason for using filter presses, the cakes from which carry much less moisture.

Glucose (Corn Syrup).—Clarifying this material free of protein and other impurities is a clarification problem solved by adding a filter aid to the liquor. Depending upon the amount of filtering material added this can be handled on a continuous or on pressure leaf filters.

Glycerine.—When obtained from spent lye liquors in the soap plant, this is a matter of handling flocculent aluminum hydrate as thrown down by the addition of alum. The hydrate predominates over the other solids of suspension. Without further treatment this liquor can only be economically handled in plate and frame filters. If fortified with a filter aid, pressure leaf filters are applicable.

Lead Arsenate.—If process of manufacture of this insecticide is well controlled continuous filters will work satisfactorily. If the batches vary through wide limits, plate and frame presses are best.

Lead Carbonate, basic (White Lead).—The delightful free filtering characteristics of this material, when made by lead corroding methods, or by carbon dioxide absorption, is ideal for continuous filters. When made electrolytically decantation ahead of a continuous filter is advisable.

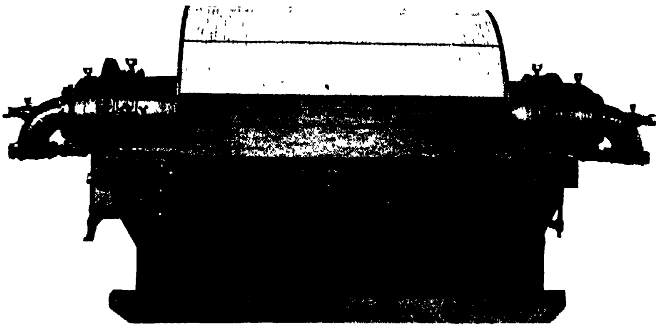
Lithopone.—Both crude and finished lithopone have been confined to plate and frame presses for the large majority of plants. The fact that without decantation the product is rather difficult to handle, coupled with the need of drying both products, has dictated the use of filter presses. One plant has successfully demonstrated the practicability of continuous filters on both products so that probably these machines will have a more general application in the future.

Magnesium Carbonate (Magnesia).—There is nothing difficult in handling this material save the crystallization that takes place in the filter fabric. This was thought to necessitate plate and frame presses but pressure leaf filters set up with a back pressure on the outlets from the leaves are handling this product most successfully.

Nickel Carbonate.—If produced for storage battery work, this product is by its slow filtering character confined to plate and frame presses. When

manufactured for electroplating purposes it is relatively free filtering and handled on continuous filters designed to prevent cake cracking which is very rapid in this cake.

Sodium Bicarbonate.—Probably no product has a greater daily tonnage than the fine crystals of this material as produced in our large alkali plants. The earliest form of continuous filter was developed for handling this product and the ease of filtration accounts for the successful operation of single compartment drum filters. Multiple compartment continuous filters are best for this work.



Courtesy Oliver Continuous Filter Company

FIG. 123.—Oliver Continuous Filter—Double Delivery of Filtrate.

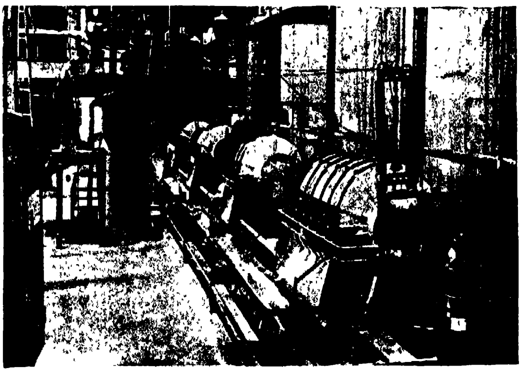
When handling excessively free filtering liquors, drainage through one valve requires a valve of unwieldy proportions. Double delivery through valves located at each end is better mechanics. This is particularly true of sodium bicarbonate crystals suspended in crude liquor.

Sodium Borate (Borax).—Handling this material is largely a case of handling calcium carbonate as the solid of suspension from a solution of sodium carbonate and sodium borate. The ore contains considerable sand which should be classified before feeding the liquor to the filter. The washing of the cake is important, but as the wash progresses the sodium carbonate, as well as the borate, goes out of the cake and the cake becomes progressively less and less porous. Nothing but pressure leaf filters should be used on this but their economy of operation will warrant scrapping of plate and frame presses to install pressure leaf machines.

Starch.—The free filtering character of this product calls for continuous filters. There is no valid reason for the use of other type machines for this work.

Sugar.—The sugar field represents one of the largest for the application of industrial filters. It is divided into two main classes: beet and cane. Cane sugar is again divisible into raw and refined classes. Rare sugars, as dextrose, maltose, mamose, etc., are special and limited.

Beet sugar liquors from first and second carbonation are best handled in pressure leaf filters, although the possibility of thickening by Dorr apparatus and handling the settlings by continuous filters is receiving attention. Cold saccharate liquors are handled in continuous filters and rotary leaf pressure filters, metallic filter cloth being used in both machines. Hot saccharate liquors are handled in pressure leaf filters or by Dorr Thickeners and continuous filters. Thick juices have been clarified by plate and frame presses although pressure leaf filters can handle the liquor if a filter-aid is added.



Courtesy United Filters Corporation

Fig. 124.—Battery of American Continuous Filters.

The elimination of large head room necessary for drum filters of equivalent area is distinctive of this disc filter.

Raw cane sugar liquors are not filtered extensively, settling the juices to a semi-clear liquor being considered sufficient. The settlings are handled in plate and frame. There is great demand for economical clarification of the semi-clear liquor but to date no modern filter has been found applicable, due to the extreme difficulty of handling this material. In sugar refineries, bag filters for clarifying the remelted sugar liquors are now supplanted by pressure leaf filters whenever the liquor has had a filter-aid added. Modern filters cannot handle these liquors without a filter-aid.

Wood Pulp.—This is a fine filter aid. Its filtration is, therefore, simple. When washing the pulp free of soluble material the continuous filter is an economizer over wet machines and repeated washings by agitation.

Chapter II.

Relation of Filtration to Other Chemical Plant Operations.

We have now outlined the theory and mechanics of industrial filters and their applications. Next, we must examine the relation of filtration to other chemical engineering operations, and by this phrase—*"other operations"*—we mean specifically, drying, evaporation, crystallization, de-colorization and distilling.

Filtration in plant practice is never the only operation. This is even true in municipal water supply, where filtration is possibly the most important function of the water works, for the clarified water must be treated to remove all bacteria. In industrial plants, therefore, the filter station must be designed with relation to other operations in the plant.

Filtration is affected by preliminary treatment, i.e., (1) grinding, (2) mixing and digesting, (3) agitation, and (4) feeding the filters. As these preliminary operations bear an influence on the work of the filters, filtration likewise bears an influence on the after-processes (drying, evaporation, crystallization and distilling).

Two products are always obtained in filtration: the clarified filtrate and the accumulated cake. This means, then, that there are two considerations and it is often the case that one is the valuable product and the other a by-product or waste, although there are numerous instances where both products are valuable. In sugar manufacture, the sugar liquor (or the filtrate) is the desired product and the solids of suspension, either as the calcium carbonate of beet sugar, or the waste mud in cane sugar work, is the waste product. In the manufacture of pigments like white lead, the solid is the valuable product and the dissolved impurities in the filtrate, —waste. An instance where both products are valuable is in the manufacture of titanium oxide where the solid is the new titanium pigment and the filtrate, strong sulphuric acid.

The increasing demand of Boards of Health for the elimination of pollution entering streams and rivers and the increasing cost of land used as dumps has heightened interest in by-product values of industrial wastes. Consequently, the after-processes by which the wastes can be economically utilized as by-products are becoming more and more important. Recovery cost has been the main factor in the rather belated interest in waste disposal in this country, but, with improved methods, success is being accomplished so that industrial waste reclamation is assured.

Section I—Influence of Filtration on Drying.

By de-watering the filter cake, the filter can aid the dryer, but the moisture content of the discharged cake is not the only factor than can affect the dryer: accessibility of moisture in the cake is also important, for drying is in reality evaporation and in thick cakes the moisture in the center is hard to evaporate. Also, the means of conveying the discharged cake to the dryer is no small factor.

It is, therefore, apparent that the cake discharged from the filter should be conditioned for drying and the operation of the filter judged largely by its ability to do this. This means that a filter must lower the moisture content and must discharge thin enough cakes for the remaining moisture to be evaporated easily. This is important, for in designing a plant, a dryer is frequently decided upon and the filter is selected which best forms the cakes for that particular dryer. The type of dryer, therefore, often determines the choice of filter. Where material can be dried at high temperatures with the products of combustion coming in direct contact with the cake, the rotating cylindrical dryer (of the cement kiln type) is generally specified. For such dryers, any filter can be used since the cake is easily fed to these machines (through ribbon or spiral conveyors). The one danger is to feed too wet or too much solid so that the material rolls up in balls in the machine and is dried on the surface only leaving the core wet.

Where high temperatures are practical, but where the products of combustion must not touch the cake, heated hearth dryers are applicable. For these machines, continuous rotary drum filters are preferable because from them the cake discharges directly into the dryer and distributes itself uniformly across the width of the dryer.

Where low temperatures are required, or where the product must be dried by indirect heating, tray and tunnel dryers are best and with them plate and frame filter presses are still preferable. The combination of these machines requires considerable labor, but if the filter press is designed to build up a cake economical for drying and large enough to deliver the maximum load per cake, the labor required is minimized. To use continuous filters, or self-discharge pressure filters, requires loading the cake into trays by hand shovelling. The labor saving, therefore, vanishes and the moisture content is not as low as with plate and frame presses.

The new FEinc Drying System was designed as a better means of uniting the processes of filtration and drying. In this the cake is preconditioned on a rotary filter and conveyed into the dryer intact, continuously and without labor. Further discussion of this system is given elsewhere.

Influence of Filtration on Evaporation.

Evaporation, whether indirect (as in quadruple evaporators) or direct (as in spray evaporators) requires clear liquor. Solids of suspension coat the heating surface or plug the nozzles and are obstructive. Therefore,

filtration influences evaporation by the quality of clarification. Clarity of filtrate is an obvious factor in the relation of filters to evaporators, but density of filtrate is probably more important. There is a balance in the B.T.U.'s saved by delivering higher gravity liquors from the filters and in the capacity of the filters working at lower densities. This balance is a function of the material in hand and should be arrived at from an economic basis. Initial cost of filter, as compared with evaporator, of maintenance and operation of both units should be taken into account. Irrespective, however, of the limiting density, the solids of suspension cannot be discharged carrying strong liquor with them. They must be washed free of the soluble material but the minimum wash water should be used. This is an axiom, even where the crude material has to be mixed with fresh water, and where in some plants this water is substituted with weak liquors. It is far better to make up any required fluidity by fresh water than to have excess quantities of weak liquor.

When high density liquors are filtered, it is universally true that they must be handled hot. The heat put into the liquors should be preserved to lessen the load on the evaporators, for it is silly to let the liquor cool off in recovery tanks and then feed it cold to the evaporator to be heated all over again.

Influence of Filtration on Crystallization.

When a liquid is concentrated to the point of supersaturation so that crystals form, it is important that these crystals grow uniformly. If the material to be crystallized contains solids of suspension, false graining often occurs, misleading the operator. Unequal crystals then form and the product is difficult to centrifuge. Clarity of filtrate, therefore, influences crystallization.

If the operator is expert, he can handle cloudy filtrate and produce crystals of almost uniform size, but crystals grained from cloudy liquors are hard to centrifugate as the mother-liquor is foul and the solids of suspension are filtered out, increasing the resistance in the basket. When the solids are not filtered out of the mother-liquor, it is a product of less value than when the mother-liquor is clean. A notable case in point is molasses from cane sugar manufacture.

Influence of Filtration on De-Colorization.

De-colorization of liquors is effected best by the absorption of the color by de-colorizing agents such as bone-black, active carbons, silica-gel, etc. Economical handling of these de-colorizing agents requires their constant re-use. If, therefore, the filtrate to be de-colorized contains solids of suspension, the accumulation of the solids becomes a contamination of the de-colorizing media. In no case is clarity of filtration more important than when filtration is followed by de-colorization.

Influence of Filtration on Distilling.

The operation of distilling is quite similar to evaporation and hence the factors affecting evaporation likewise affect distillation. The marked

Courtesy Filtration Engineers, Incorporated

FIG. 125.—FEinc Drying System.

The conveyance of the ribbon-like cake from the continuous filter into an automatic loop dryer is the distinctive feature of this system. The filter operation is simplified in the matter of discharging so that the FEinc Filter equipped with a FEinc Cake Compressor is a unit in the system.

difference is that in many cases the final residue in the still is made unnecessarily viscous by the solids of suspension.

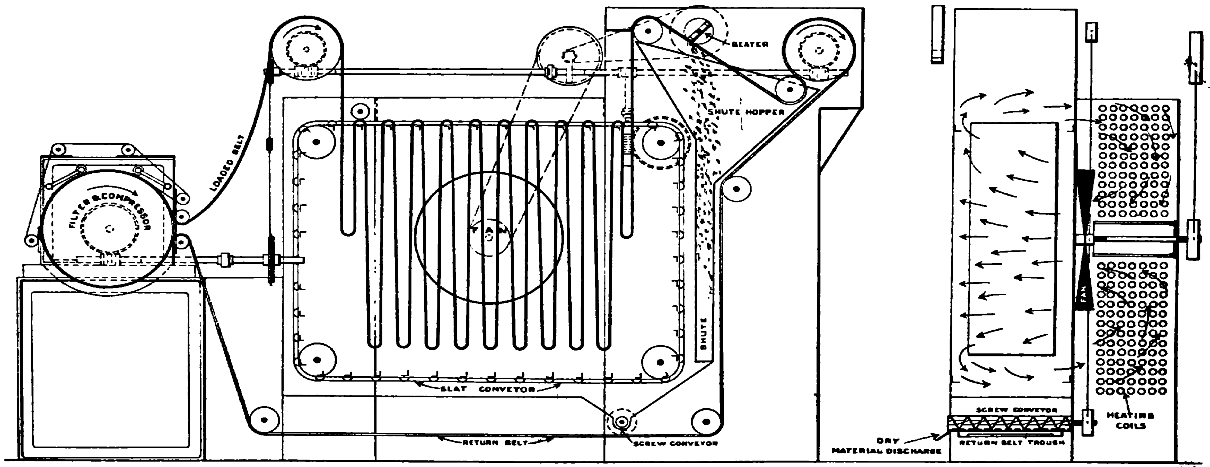
In a well designed or well operated plant, no one chemical engineering operation is independent of the preliminary or subsequent operations. Filtration is no exception and the filter-station must co-operate with the dryer, or the evaporator, or whatever follows the filter. Efficient filtration has spelled success for many chemical processes and lack of it has meant failure for many others and efficiency requires that the filter station be designed with the subsequent operations well in mind.

Section II—Combination Filtering and Drying. FEinc Drying System.

The FEinc Drying System has proved to be an interesting development as an instance of the combination of two major chemical engineering operations in one machine. There are pulverizors which also screen their product, evaporators in which the crystals are separated from the mother liquor, conveyors which are simultaneously agitators, etc., etc., but the FEinc Drying System is the pioneer in uniting industrial filtration and drying.

If industrial filtration is defined as the separation of solids from liquids the FEinc drying system is the first machine to fulfil this definition completely, for it starts with a slurry of solids and liquids and delivers a clarified liquid at one point and dry solids at the other. In the comprehensive scope of this definition of filtration we are led to the realization that drying is supplementary to filtration and the duty of the dryer largely dependent on the work of the filters. The FEinc Drying System owes its origin, in a large measure, to an appreciation of this fact.

As engineers seeking better results from industrial filters, the Filtration Engineers, Incorporated, evolved their FEinc cake compressor. This device makes possible the discharge of cakes closely approximating the minimum moisture content. This is an advance toward bettering the work of the filter and decreasing the duty of subsequent dryers. While investigating the possibilities of the cake compressor for the United Lead Company, as applied to the filtration of their white lead, the form in which the cake was discharged was a factor. Hand labor had to be eliminated, as there is always a possibility of some white lead drying, becoming dusty, and then poisoning the operator. To discharge it upon a heated hearth with an automatic raking device did not prove feasible as the discharged cake is heavy and sticky. In some previous work on acid filtrations a cake stripping device was worked out to transport the cake deposited on the sand filter to a discharge hopper. To incorporate a means of stripping the cake from the continuous drum was quickly seen to offer immense possibilities. The first experiment was a success and proved that not only was the cake removed from the filter but it was conveyable and as such amenable to a radically different means of drying. The conventional loop dryer as used for textiles, impregnated paper, etc., could now be synchronized with the operation of the filter. Initially,



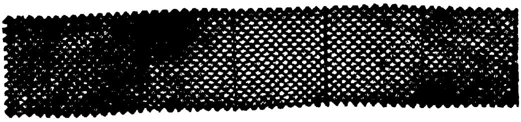
Courtesy Filtration Engineers, Incorporated

FIG. 126.—FEinc Drying System—Festoon Type.

The loaded belt is pulled over into the top of the dryer and falls between girts carried on link belt chains moving at slow speed. There is no further lineal travel of the belt, the loops slowly moving through the dryer and across the circulation of conditioned air. The dried material is vibrated from the screen into a hopper, the boot of which empties into the main cross conveyor located so as to catch any droppage as the festoons are taken up off the girts.

therefore, the FEinc Drying System was the linking together of a standard rotary drum filter and a standard loop dryer.

Design.—The linking member, and, therefore, the key to this system of drying, is the conveying belt. Its specifications include being non-absorbent, non-corrosive, capable of reinforcing the cake so as to hold it enmeshed, capable of turning pulleys without strain and of sufficient strength to insure long life. It must be obtainable in different thicknesses as successful operation requires a reinforcement throughout the depth of the compressed cake. A flat screen giving a surface reinforcement only is unsatisfactory for while it may lift the cake from the filter, it will not support and hold the cake when looped in the dryer. The enmeshed cake must be secured in the conveying belt, even when thoroughly dried, or otherwise premature droppage will be excessive and the dusting effect heavy. The conveying member made of spiral woven wire of iron, bronze, copper, monel, aluminum, etc., answers the specifications as it is obtainable



Courtesy Filtration Engineers, Incorporated

FIG. 127.—FEinc Drying System—Section of Conveyor Belt.

There is a strong analogy between this specially spiral woven belt and bed spring construction. Besides being resistant to the material in hand, the belt is also capable of turning pulleys without strain, maintaining alignment, and of sufficient strength for long wear.

in thicknesses varying from 1/8 in. to 5/8 in. Thicker cakes than 3/4 in. are not economical, as the time of drying varies in a greater ratio than relative thicknesses and the cakes are generally held under 1/2 in.

The successful conveyance of the cake depends upon sychronizing movement of dryer and filter and proper alignment of belt. The actual lineal speed of the belt leaving the filter is indeterminate. The filter drum is made with a drainage member which is somewhat flexible. The filter cloth is, in effect, springy. Any cake remaining on the cloth increases the length of belt covering the drum and the lineal speed is again changed. There is, however, one positive feature,—there is no slippage of belt around filter drum. The driven pull drum in the dryer which carries the loaded belt from the filter to the looping mechanism is a pulley with rigid surface. By designing this drum of proper diameter sufficient contact can be obtained to minimize slippage. Any caking of solids on its surface would be fatal, but it is always hot and its dusty surface prevents any cake adhering to it. Consequently, a variable speed drive is inserted to regulate the relative rotative speeds of pull drum and filter and to maintain synchronous lineal speed.

The solution of alignment difficulties is simple. Take a leather belt driving a line shaft. It requires a decided thrust to deflect the driving

side of the belt and an insignificant thrust to guide the slack to a new position. Therefore, the conveying belt must be aligned at points of minimum tension. There are several in the machine but the only one of pertinent value is that of the returning belt just re-entering the filter tank. Having the filter shaft and pull drum accurately aligned means that guiding the conveying belt on to the filter likewise guides it on to the pull drum and, therefore, into the looping mechanism.

These few features mark the main points of the successful linking of filter and dryer.

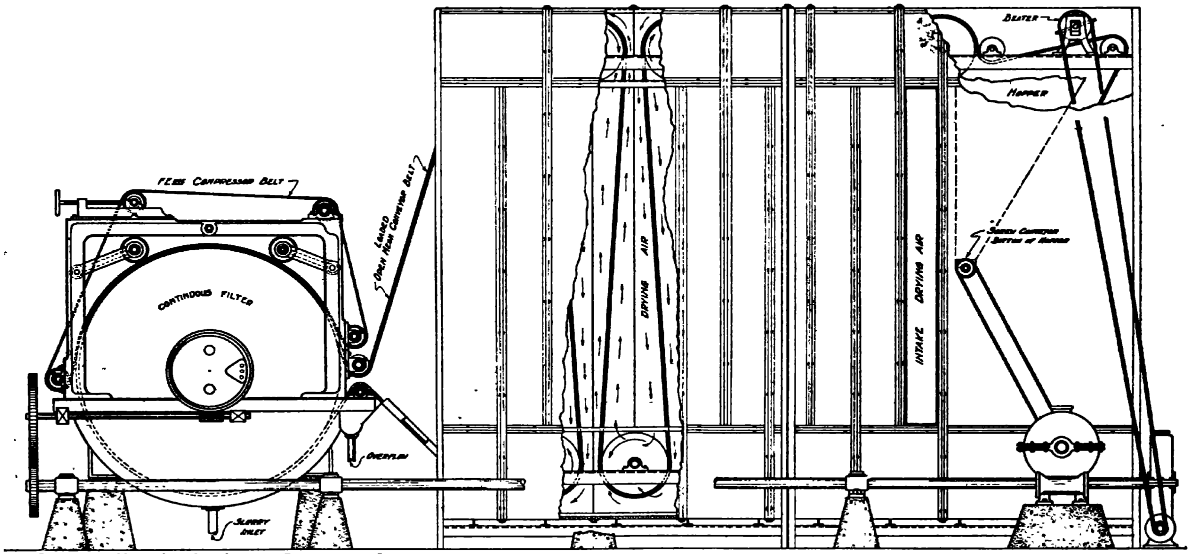
The dryer proper has been developed in collaboration with Proctor and Schwartz, Incorporated, starting with their standard textile loop dryers as a basis. The cardinal features of their design are, recirculation of drying medium, simple mechanics of driving parts, location of discharge hopper, panel insulated enclosure and dust elimination.

The drying effect is a function of the accessibility of the moisture, the temperature at which the drying takes place, the condition of the drying agent and the amount or velocity of the circulated air.

If two dryers are considered, one operating on a bolt of wet silk and the other on blocks of magnesia, we have an example of first, a material in which the water is accessible and second, a material in which the water is inaccessible. In the first instance, the moisture is practically on the surface of both sides of the silk and can be dissipated from both sides. The thinness of the cloth makes any moisture in the interior easily reached by the drying air. In the second instance, the blocks are often laid in trays lined with cloth, the circulation through which is restricted. Practically, the drying takes place from one surface only. The thick cakes house much of the moisture in the interior away from the surface, and to dry the surface rapidly has the tendency to check further drying effect of the interior by the non-conducting layer of dried material. Obviously, then, the drying operation is easier when the moisture is accessible.

The temperature of drying is limited with every material. With some, that temperature may be at which organics present oxidize; with others, the temperature must be below the point at which water of crystallization is given off; and with others, it must not exceed the breakdown point of the material as the transformation to dextrine in starch, the liberation of carbon dioxide in carbonates, etc., etc. In every case, however, the higher the temperature within the limits of the material, the better. To have evaporation by combining ebullition and the humidity carrying effect of the drying air is to effect it most rapidly. There are more heat units in hot air than warm air, and, consequently, the temperature of the material itself more quickly brought up to the boiling point. With thin cakes this temperature is uniform throughout the mass and the difficulties of a dried surface and wet interior obviated. Also, the metallic wire of the conveying belt in the FEinc Drying System conducts heat into the center of the cake with marked efficiency.

If the temperature is held above 212 degrees Fahrenheit there is no saturating the air with moisture, as all the water evaporated is carried as dry, superheated steam. If the temperature is under the boiling point



Courtesy Filtration Engineers, Incorporated

FIG. 128.—FEinc Drying System—Series Roller Type.

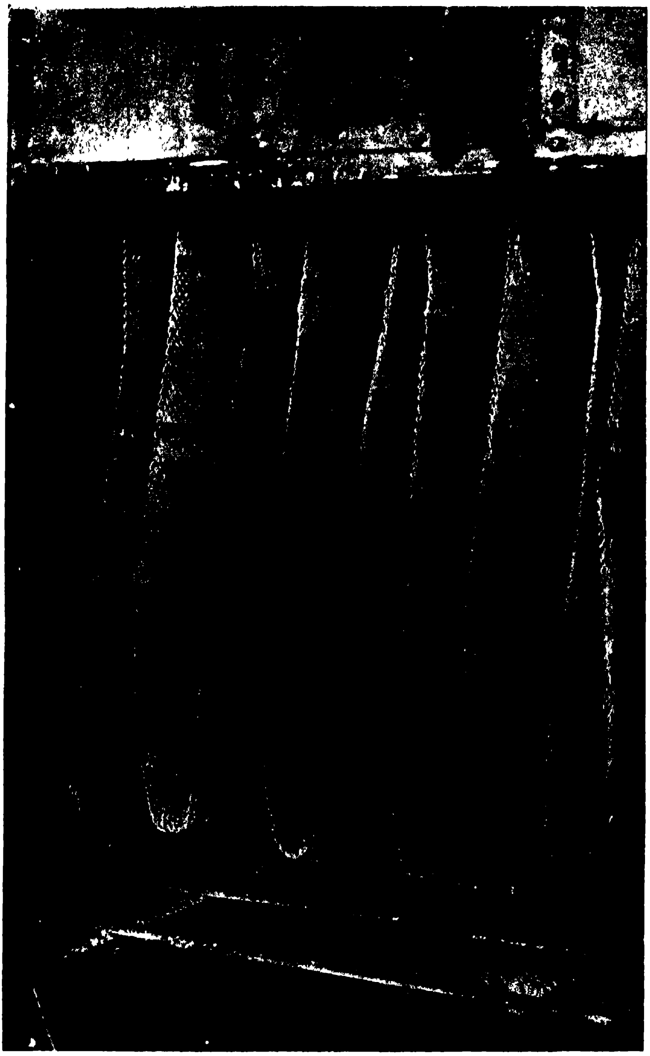
With a finely divided precipitate that is firmly engaged in the conveyor belt, it is practical to convey it over pulleys counter-current to the passage of heated air. With such materials loss by droppage from the belt is less than 1 or 2% and the drying economy high.

at atmospheric pressure, the higher the temperature the greater the moisture carrying power of the drying air before reaching saturation. When dealing with air at lower temperatures relative humidity is of utmost importance. The efficiency of Proctor Dryers is founded on the added drying effect of an air of lower relative humidity. The decrease in relative humidity is obtained by again raising the temperature of a majority of the air which has swept across the cake, picked up moisture and had its temperature lowered, and mixing in a quantity of dry air to make up a constant volume. That air which does not have its temperature raised is vented as wet air and exhausted from the system. This reheating of the used air and mixing it with fresh dry air maintains the drying medium in good condition for drying.

Commercial drying maintains that condition under which the family wash always dries quickly. When the wet linen is hung out to dry, sunshine is always wanted, but is not necessary if a breeze is blowing. The wind carries away the moisture by its humidity carrying power and by continuously sweeping fresh air across the clothes. The velocity of the air is an important factor. In Proctor Dryers this velocity is maintained at a high rate, commensurate with the best drying effect of the material in hand, and, at the same time, is maintained uniformly throughout the machine. The latter is effected by moving large quantities at a time, by large fans, as compared with numerous small jets from small fans.

Recirculation of the drying air in Proctor Dryers is a mechanical means of maintaining conditioned air in the dryer. It sweeps the dry air across the wet cake and returns it through heating coils to again sweep across the cake. Large disk fans, of exact design, having a maximum throw longitudinally and minimum radial throw, effect this circulation. An exhaust fan at the wet or inlet end of the machine, regulates the amount of wet air exhausted. The fan is set to throw out sufficient wet air to maintain a conditioned air for best economy of drying in respect to time required, and B.T.U.'s consumed. The recirculation fans are located so that the blast of reheated air will not set the festoons swinging and so that all the returning air must pass up through the heating coils. If hot waste gases are used directly the mixing of the fresh hot and partially spent air takes place in the chamber on the suction side of the fan.

One long shaft drives a pull drum at the inlet end and one at the discharge end. These drums or pulleys form and take up the festoons respectively. A shaft at much slower speed revolves the drive sprockets of the link belt chain that carries the festoon holders or girths. The festoons are formed by the loaded belt, falling from the inlet pull drum, looping over successive girths carried on the slow moving link belt chain. As a full length of festoon forms, the girth comes in contact with a cut off idler that prevents further movement of the belt on that side of the girth and starts a new loop on the other side. The idler holds in contact with the girth until sufficient length of new festoon is formed to prevent the shorter length being overbalanced by the full length festoon. At the discharge end, the drum pulls up the festoons at the same rate at which they are formed, so that making and withdrawing the festoons is con-



Courtesy Filtration Engineers, Incorporated

FIG. 129.—FEinc Drying System—Dried Cake on Screen.

When the loaded screen enters the dryer all linear motion of the belt ends as soon as the festoon is fully formed. The forming of the festoon is accomplished while the cake is wet and adherent. Through the dryer the loops are carried by translation and without any linear motion. This, coupled with the true volume reinforcement of the spiral woven conveyor belt, securely holds the cake in the belt even after all the moisture has been dried out of the solids.

tinuous. The cleaned belt is pulled back by the rotating filter, the lineal speed of which is adjusted to equal that of the pull drums. The returning belt drags along the bottom of the machine, and acts as a drag conveyor for any material that may have fallen in forming the festoon, or due to poor enmeshment in the belt, and propels such material to a water seal, where it is wetted and hangs to the belt as it goes into the filter, or to a cross conveyor when the material is sufficiently dry to be mixed with the finished product.

As the dried festoon is being pulled up by the drum, some material breaks out and falls, the remainder adhering in the belt to be shaken free by the vibrator. The material that breaks out lands in the main discharge hopper, and instead, therefore, of being a problem to be coped with, is a help in cleaning the belt. The material shaken from the belt by the vibrator falls down a chute, emptying into the main discharge hopper.

No dryer room or chamber is well designed that does not allow of ready access to any part. In the Proctor Dryer, besides adequate observation doors, the entire enclosure is panelled. Any section is readily unbolted and accessibility to any part of the machine obtained. Each panel carries its own insulation, which is sufficient to make radiation loss very low.

The dried material breaks out of the belt in small lumps or nodules, so that dusting is minimized, but, further, the dust that does occur is localized at the discharge end and isolated from the windage of the recirculation. Dusting is, therefore, easily confined and loss on this score eliminated.

Operation.—The drive of the filter is coupled with the drive of the dryer. After adjusting the variable speed drive so that the lineal speed of the filter equals the speed of the pull drum every other operation is automatic and requires no more attention than that required by automatic drum filters equipped with cake compressors.

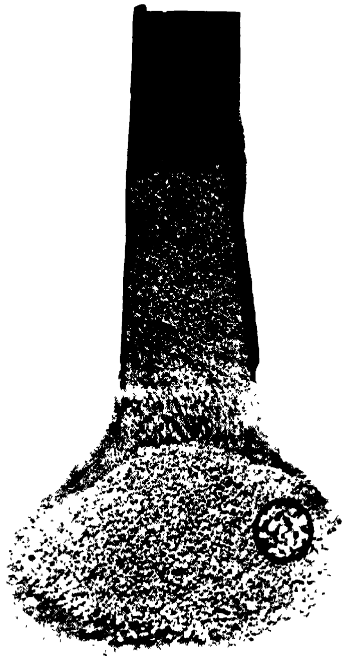
Layout.—The drying chamber extends as a rectangular box from the filter. In addition to providing room for the main and fan drives sufficient aisle space should be left to make renewals, such as a bank of coils, fan shaft, etc. Such repairs are seldom required, but are serious when no room is provided to remove them.

Advantages.—Combining two operations in one continuous machine is the obvious leading advantage of this system. It becomes a new unit, a filter-dryer, and, as such, there is no break between filter and dryer. To go from a given slurry to clarified filtrate and dried solids in one machine represents many short cuts in process, in handling and in machinery.

The leading operating advantage would seem to be its fool-proof and simple operation. In one plant a foreigner who had a full day's job pumping solutions from one station to various parts of the plant had the operation of the drying system added to his labors. He was not overworked, for, aside from reading a thermometer to make sure his steam pressure was up, he had no more work than is entailed in operating a rotary drum filter. He cannot overload the dryer, he has no regulation

of the steam pressure save to slow down the machine if the boiler pressure drops. It is truly automatic throughout and so long as the filter end functions the dryer end takes care of itself.

The uniformity and positiveness of drying is probably the vital advantage. All the cake is held to a uniform thickness and every particle



Courtesy Filtration Engineers, Incorporated

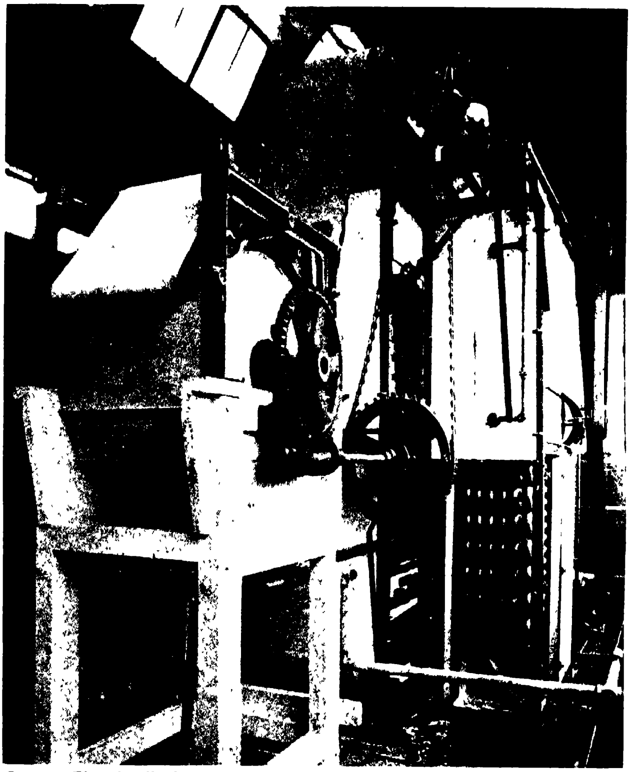
FIG. 130.—FEinc Drying System—Characteristic Discharge.

The dried product is vibrated from the screen so that the discharge consists of small granules or nodules of approximately ¼-inch cake. These small lumps represent the openings in the weave of the belt and by their bulk automatically reduce dusting effect and are ideal for calcining, roasting, etc.

passes through the same drying atmosphere. The operator cannot shorten the travel and, therefore, the time of drying, and since the entire cake remains in its ribbon-like form there is no balling up of material the core of which remains wet. The festoons hang from girths on equal centers so that the circulation of air is uniform over each festoon which again insures uniformity of drying.

The efficiency of this system is comprehensive including both that of

filtration and drying. It is high, for the cake compressor cuts down the moisture by mechanical means and the filter delivers a well dewatered cake. The accessibility of the moisture in the thin cake allows each cubic



Courtesy Filtration Engineers, Incorporated

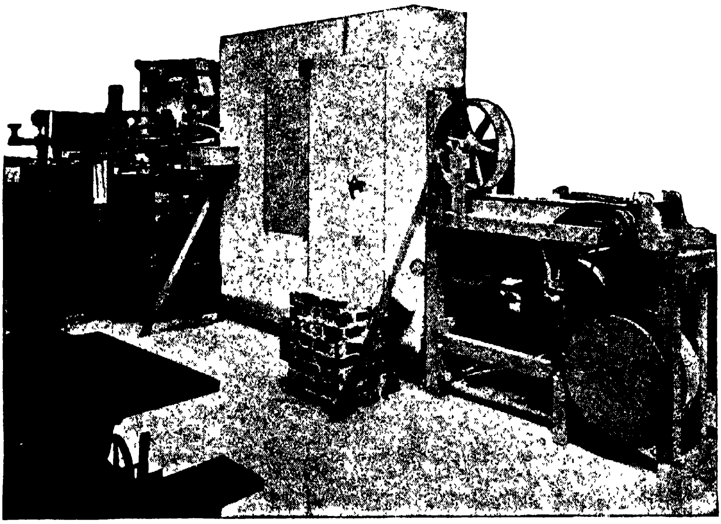
FIG. 131.—FEinc Drying System—Steam Coil Type.

The Proctor system of recirculation of the hot air first across the loops and then back through the steam coils, provides a simple and most efficient use of the steam. The coils are located in a separate chamber behind the loops, and the several manifolds are arranged for quick assembly or repair as well as to accommodate the shaft of the fans belt-driven from the main drive shaft. Coil dryers are controlled to any fixed temperature and positive freedom from contamination on the cakes is always assured.

foot of circulated air to do maximum work so that the actual drying efficiency is also high. The economy of operation is, therefore, best expressed in terms of pounds of steam per ton of dried material.

The applicability of this system to large tonnages and waste products is an advantage. Large deposits of waste calcium carbonate, calcium sulfate, hydrate of lime, etc., can be economically handled by waste heat or live steam so as to make profitable their disposition as by-products. Many such products have resisted reclamation prior to the advent of this method of drying.

Drawbacks.—Granular materials that will not cake and enmesh in the conveying belt are better handled in rotary cylinder or heated hearth



Courtesy Filtration Engineers, Incorporated

FIG. 132.—FEinc Drying System—Experimental Series Roller Type.

The compact arrangement of this outfit obscures the wide variation in mode of operation possible with such an unit. The entire mechanism is self-contained and allows great freedom in methods of filter operation, as well as means of drying the product. The small combustion chamber serves to completely burn illuminating gas and to thoroughly mix the gases so as to feed uniform temperatures to the drying compartment.

dryers. It is the first essential that the cake remain in the belt during its travel through the drying chamber.

Very thin cakes of insufficient thickness to enmesh in the conveying belt are best handled by plate and frame presses and truck and tray dryers.

Linking filtration and drying in one operation means that a shut down stops both filtration and drying. This drawback is diminished if the system is designed with at least 20 per cent overload, for then sufficient time is provided for make up capacity and this holds production uniform.

The conveying belt is made of metal. When handling weak acid slurries this metal is subject to weak and strong acids, due to concentration in the dryer. The corrosion of the metal becomes a factor preventing the use of this system.

Applications.—The FEinc Drying System is designed to handle the cake delivered from rotary drum filters. Therefore, wherever rotary drum filters are applicable, so is this drying system.

It is pre-eminently applicable to those materials requiring drying by indirect heat, such as pigments, food products and high grade products. These materials have been confined to truck and tray dryers, and being able to eliminate the hand labor incident to their operation is a big incentive for the application of the continuous system.

The application to waste product recovery is destined to be of first importance. Recovering waste lime from acetylene manufacture; calcium sulphate from phosphoric acid; whiting from causticizing; solids from municipal sewage disposal, etc., have all been successfully handled.

Chapter III.

Plant Practice.

The efficiency of the filtering operation is, naturally, judged by the work done in the plant. Plant practice should equal results obtainable in laboratory tests and it *can* equal these results when care in the layout and in filter operation is taken. The principles involved in factory operation are the same as in the testing machine. It is only in the matter of manipulation and maintenance that there is a difference, and here lies the chance for much improvement in many installations in practically every field.

Cleanliness.—It is almost proverbial that the filter station is the hardest part of the factory to keep clean and free from sloppiness. Especially is this true when using plate and frame presses as the leakage from these means a constant cleaning up of floors. Cleanliness of itself may seem remote from increasing efficiency of the filters but in actual experience it is vital; first, because sloppiness indicates a loss; second, cleaning up takes time of the operator which might be better used; and third, the morale of the operators is weakened by slouchiness. The work cannot be done with the same pride if conditions border on the unsanitary, as when the filter station is kept clean and neat. A very definite example of this was shown when a large borax manufacturer substituted Sweetland filters for recessed plate presses. The operators previously worked in overalls and rubber boots and at the end of their shifts were always badly bespattered with slurry. Now the men merely slip dusters over their street clothes, rubber boots are dispensed with, they quit work clean and to-day the filter job is sought for by the men in the plant. It goes without saying that results obtained with these filters are far more uniform than were formerly obtainable. Even where plate and frame presses are used, it is proof that cleanliness can be obtained for when one visits several sugar mills in Cuba he is struck with the noisome conditions in some plants and the clean and sweet smelling stations in others. Where orders require that the filter floor be kept clean it is noted that the operators take more care in laying filter cloths and in keeping gaskets clean. It does not cost money to keep the filter station clean,—it saves money. Some of the savings are tangible in reduction of unaccountable losses, others are intangible in better morale. It is possible, therefore, to maintain cleanly conditions on the filter floor and cleanliness is a guide as to probable efficiency of a station. Therefore, in the control of the filters in plant practice, cleanliness is vital, and the first point that the superintendent should insist

upon. With modern filters, uncleanliness is a mark of gross negligence, as there is no valid excuse for such conditions.

Health Conditions.—It is obvious, when handling poisonous materials such as insecticides; poisonous pigments; corrosive acids and alkalis, that the operator be protected. It is not quite so obvious when handling food products or inert materials such as starch, beet sugar, liquors, whiting, or iron hydrate, etc. It is, however, equally important that good, healthy conditions be maintained in such plants also. When handling hot materials, the evaporation of which increases humidity and temperature of the filter room, or again where solids, which when dry are dusty, are allowed to accumulate to raise a dust, are typical of the unhealthy conditions incident to the handling of non-poisonous materials.

Healthy conditions are not required only from the humanitarian standpoint but from best business point of view. It costs money for sugar refineries to install ventilating ducts with exhaust fans but it makes better conditions under which to operate the filters and reduces the labor turnover. This is a health protection that warrants the expense.

The moving parts on filters are comparatively few even including the auxiliaries, pumps for instance. This fact has caused many plant superintendents to overlook the usual safety guards around pulleys and gears. On analysis this is dangerous. Most operators wear overalls, the bottoms of which are often rolled up as a trouser collar. The hazard of this collar getting caught between the belt and pulley is obvious. Safety precautions are insisted upon in plants enjoying good records for economical production.

A casualty hazard better appreciated is slippery floors. Spillage of a filter slurry on concrete or wooden floors creates a condition closely approximating a greased slide. Where such leakage is prevalent the floor should be pitched to drain to a sump. A water hose with good pressure should be kept handy to frequently wash down the mess and good substantial duck boards or gratings should be laid on the passage ways. Cane sugar mills are an outstanding example where such precautions are necessary and pretty well provided.

The wear and tear on valves and fittings, especially flanges, is heavy in handling chemical factory liquors. Leaky joints are easily stopped if the flange bolts are tightened or new gaskets inserted soon after the leakage is detected. If one leak is allowed to continue it soon is a matter of several others starting and progressing until it requires a shutdown of hours. This cannot be done without sacrifice of production. This means a postponement until the condition becomes so serious as to demand repair. All the time that leaks occur there is the hazard of blinding the operator, of scalding him, or in other ways injuring him. This condition is positively unnecessary and is rapidly becoming obsolete in most American plants. Where it does exist the plant executives do not appreciate the danger and the lowering of the morale of the operators. In this connection, plug cocks should never be used after the thread at the base of the plug has been crossed or broken. On more than one occasion it has been observed that in shutting off such a valve, the plug

has been driven out of the cock and the operator narrowly missed serious injury on each occasion. Likewise bad burns from steam valves, the stuffing boxes on the stem of which were not tight are examples of unnecessary and bad plant conditions. Steam economy has been so well discussed that any chief engineer worthy of the name will censure any such condition in his plant as a steam loss which directly reflects on his department. The chief, however, should never be worried with such trivial points and never need be if the operators on the filter station have their own tool box with a few wrenches, packing, grease, etc. The duties of filter men are never so arduous but that they have plenty of time to take care of these minor repairs themselves. No real skill is required for such jobs and bringing pipe fitters, machinists, or other mechanics up to do such work is poor management.

When heavy caustic, acid or other corrosive liquors are handled protecting the operators by rubber gloves (without holes), rubber boots, and goggles for the eyes is standard practice in the United States. The danger in such work is obvious and there is but little cause for complaint in such plants. It is a long time since the cost of making sure that these protections are in perfect condition and imperfect ones immediately replaced by new pairs, has been counted as an operating cost. It is rightfully overhead expense and theft is the only cause for checking the number of replacements.

When handling poisonous solids like insecticides, white lead, etc., the plants throughout this country are pretty well equipped with dust eliminators. Yet, it is amazing how unappreciated is the fact that spillage when dry becomes a source of dust. Or, again, that the men's overalls that have been dirtied with wet cake or slurry are a true source of dust as soon as the cake dries. It is not, therefore, in a sense of being unduly apprehensive that superintendents of the best operated plants require all spillage to be removed immediately and all operators to change their uniforms at least once a day, and each operator to take a shower bath before changing into street clothes. In some plants doctors go so far as to inspect men's finger nails, —it pays. A sick operator may be brought back to health but his sickness represents a greater loss than the half-pay given him while he is out. There are plants where operators have worked continuously for more than twenty years. Their work has kept them in contact with white lead ten hours a day and yet they are fine specimens of health to-day. Such examples are best proof of the value of constant precaution against dust contaminations.

Necessity for cleanliness in a plant is to-day more and more appreciated. Cleanliness paves the way for healthful working conditions; maintains morale; reduces labor turnover; and assures steady operation and production which is the first requirement of plant practice.

Accessibility.—To obtain good operation of filters in the plant irrespective of type, the first essential is accessibility. Where the machines are the intermittent type, particularly, this may mean valve manipulation, or with any filter it may mean ability to observe performance of the machine.

The matter of valve manipulation is generally well provided for when machines are installed according to standard layouts. The old practice of bringing the various pipe lines to the filter and locating valves here or there made valve manipulation an art. This heterogeneous arrangement of valves has no place in the plant desiring good filter performance. The need for accessibility to valves is not a matter of lightening the work of the operator so much as it is a necessary means of enabling the operator to handle valves simultaneously, as is required in leaf filters.

The operator must depend upon the cake formation as his best indicator for operation of the filter. Irrespective of the kind of filter or the work to which it is applied, this is equally true. On continuous filters any housing over the exposed drum should have openings through which cake can be observed or observation windows answering the same purpose. Leaf filters should be located so that by walking along the machine each square inch of the filter area can be observed by the operator. Sweetland filters, when mounted so that the gasket joint of the two halves is about the height of the man's eyes as he walks along, are most accessible in this respect. On the other hand, when the break is located only waist high, requiring the operator to bend low and crane his neck, a filter is awkwardly inaccessible. Such conditions are never necessary and are good reasons for inefficient operation.

Foremen of departments, superintendents and others in control must judge the operation of the machines by daily reports and by the casual inspection they give on their rounds. The more accessible the filter area the more positively they can control the operation.

Control.—In the factory the machines are in continual operation. Any tendency to fall off in production, to fail in washing the cakes satisfactorily, or to deliver the cakes with too much moisture, must be checked as early as possible.

It is to be assumed that every operator is conscientious in endeavoring to get the most out of his machine. There is no better means of aiding him to perform his job than to have a formal printed report sheet which he must fill out. This sheet must have real importance in the eyes of the operator. It can have this only when it is checked up immediately after being turned in. To tell an operator on Wednesday that on Monday his production was down by 20 per cent is a warning given too late often to be effective. If checks on the daily report require analysis from the laboratory, the laboratory work should be so laid out that the data accompanies or follows very closely upon receipt of report from the superintendent's office.

The practice found in one plant where filtration and recovery of the liquid from a waste precipitate were the basic operations, there was installed a monthly graph showing production per day and average soluble left in cake. One set of these graphs was put on the wall by the superintendent's desk and a duplicate set on a board located in front of the filter foreman's table. Any sharp breaks in the curve usually had red ink explanations written along the ordinate at that point. These graphs so strikingly told the story of the filters' performance over periods long

enough to make comparison simple and easy, that it is small wonder that they are getting 25 per cent more work from the filters than had hitherto been possible. The experience in another plant proves how valuable it is to aid conscientious operators in better handling of their job. A plant was recently visited where it was essential to deliver washed solids under a certain maximum per cent of soluble and at the same time to conserve the amount of water used which later had to be evaporated. There naturally was a nicety of control which this particular operator handled exceedingly well. It was noticed that he had a complete titration outfit at a table behind his desk. His helpers would bring up samples of washed filtrate, make quick titrations, taking all their own readings and refer to a chart which gave them directly the amount of soluble present. This titration was not as exact as would be carried out in the plant laboratory, but the point is that these men were able to determine for themselves the progress of the washing operation without having to wait for determinations reported from the laboratory. It was also seen that the foreman took his own sample of the cake independent of that which was sent to the laboratory. He weighed up his own distilled water, filtered off the solid and titrated the wash water. Here again his titrations were not plant records but were checks upon the operation of his own machines obtained before the new cycle operations had hardly begun. The superintendent of the plant was proud of the record of his filters and the operators at the filters were equally pleased and jealous of their record. This is an outstanding example of how it pays to assist the operators to better their work.

In plants where conditions as above outlined prevail, control of operation (by laboratory analyses and formal reports to the superintendent) is very simple and effective. Where the co-operation and coordination of plant and laboratory are not so well maintained, the control is much more difficult. Generally an assistant superintendent has to give the filter department far more attention than should be required. Even then, too often the machines work fine while the assistant superintendent is on hand only to operate just the reverse after he goes on to another department. This failure to obtain good results does not indicate inefficiency caused by slacking up when the boss's back is turned so much as the operator's lack of self-confidence. One of the earliest Sweetland filter installations was put in a plant where several batteries of plate and frame presses were working. One operator per shift was elevated from each filter crew. One man was able to speak very little English and another almost illiterate. The process superintendent was strong technically but a little weak in handling his men. As he stood by, each of these operators were on their toes and seemed to manipulate valves as though they had learned the successive operations by heart. When the superintendent was not around they almost faltered in the manipulation. In less than a week, however, the essentials of the principle of operation was realized by each of the men and the machines operated uniformly whether the superintendent was present or not. After more than two years' operation a rough laboratory outfit was installed so that analyses, capable

of indicating the work of the filters, were quickly obtainable. To-day, more than eight years, two of these men are still handling these machines and the uniformity of results is one of the most striking ever seen. Self-confidence on the part of the operator is the best possible control of the filter. Control in order to maintain efficiency of production is largely a matter of organization. The same problems as apply in every department of co-ordination and in handling labor apply also to the filter station. However, when a radical 'drop' in performance occurs, then a technical control is far more urgent. At these times the trouble is quickest located and remedied if the filter is set up so as to be easily tested. This will mean that calibrated tanks for the filtrate and wash-water can be put into use. Often this does not mean separate tanks for this purpose but tanks into which filtrate from one filter only is being discharged. It will also mean that there are facilities for weighing the cake discharged. It should mean that there are printed forms on which the data can be recorded and computations made. If the plant has a filter, either one of the operating machines or a test machine to which can be supplied the material being fed to the plant machine, it is easy to make the test quickly and conveniently. Here is an agent of control that is too often overlooked.

Causes for irregular performance of industrial filters are being more and more known. But any one result may be caused by any one or a combination of several factors. There are times when the only answer lies in factory test. These tests are made always holding all factors save one constant and determining the real trouble by the process of elimination. Having facilities for technical investigation has advantages beside production, maintenance, and high efficiency of performance for it enables modifications of process to be watched accurately and a nicety of control set for processing the material before filtering.

As stated in a foregoing chapter on "Theory of Filter Application," filter difficulties are apt to lie in (1) material of construction and (2) in cake discharge. Practical remedies for these troubles may be worked out in plant practice along the following suggestive lines.

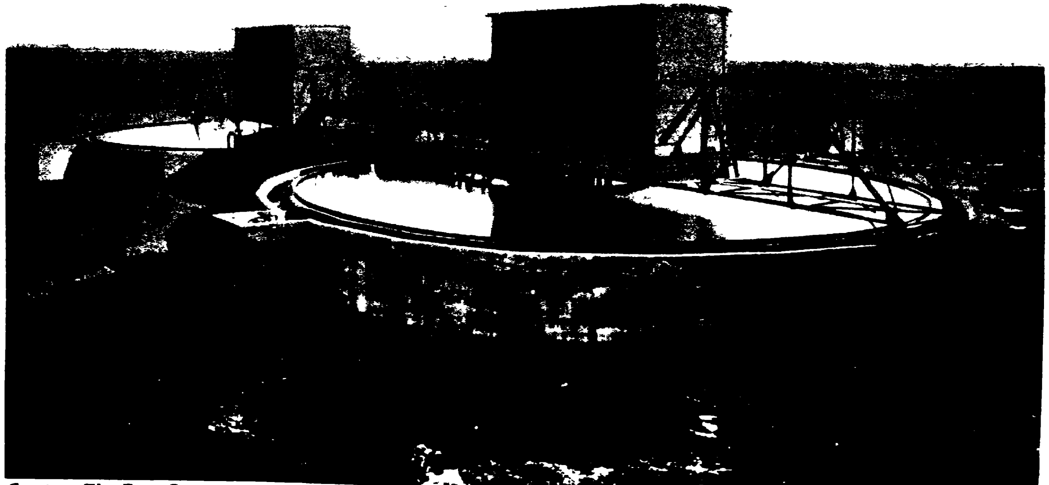
1. Materials of Construction.

When handling acid liquors the amount and nature of acid present will dictate the materials of construction to be used. But little reliance should be placed on protective paints even when handling weak liquors at relatively low temperatures. The coating is likely to be imperfect even when successive coats are applied, due to the practical difficulty of getting a clean, dry surface on which to apply the coating. The bond between the coating and the metal or material used is not great at best, and one small exposed spot is sufficient to soon nullify the whole coating. Enamel coatings are thoroughly resistant when well applied and free from cracks. Difficulty with this type of coating arises when working on liquors the temperature of which varies from room temperature, for the metal expands at a rate different to that of the coating and cracks in the coating then develop. Much improvement in this respect has been effected by

enamel manufacturers, and there is hope that eventually this difficulty will be overcome. Lead is highly resistant, but has the unfortunate property of expanding without contracting correspondingly. This is what gives the open tank filters such advantage, for the creeping of the lead is in no degree as serious as with closed containers. In weak acids several alloys are put out which stand up sufficiently to be practical materials of construction. Here, however, as with the use of monel metallic filter cloths, the design must not allow local electrolytic action to be set up by the use of two dissimilar metals or alloys whose electrical conductivities are not approximately equal.

2. Cake Building and Discharge.

In pressure leaf filters the difficulties are largely due to the operator's inefficiency through ignorance or negligence. Specifically, pressure leaf filters have been found lacking, due to poor discharge of the filtered solids, and to poor washing of the solubles from the deposited cakes. An instance of this is found in the failure of Sweetland and Kelly filters to hold their own in our beet sugar industry where Dorr Thickeners are beginning to come in. In a large measure these defects are caused by improper cake building. This may be due to poor agitation of the sludge in the filter, giving rise to tapering cakes, the thicker portions of which prevent good wash-water circulation. Such trouble should never exist, however, in rotatable leaf filters such as the Vallez. There the trouble is more likely to arise from uneven concentration of solids of suspension, making it hard for the operator to gauge the time to shut off filtration. If he delays too long, the cakes are too voluminous and adjacent cakes may have joined. If he stops too soon, the excess unfiltered liquor will be too great and washing is made difficult through enrichment by the strong liquor. To overcome this, attempts have been made to try the cake thickness by means of cake testers. These are but makeshift arrangements as they require extra attention from the operator and are not fool-proof. Granting that the tester registers the cake thickness,—it does so only at the point where the tester is located. If the filter cloth at that point is not representative, the tester is obviously misleading. The only proper means of gauging cake thickness is by experiment after accurately knowing the concentration of the solids. Such a gauge should be part of every filter operator's equipment, and must, from its nature, be home-made. All that is required is a pair of test-tubes with a graduated scale. One of these tubes is filled from a test cock on the inlet line while the filter is filling with liquor; the other is filled after filtration has commenced and serves only as a check on the first sample. Allowing these samples to settle for any determined length of time will indicate the volume of solids present. The graduated scale should be constructed from experience to read directly in terms of filtration-time. Reading this scale then gives the operator a gauge on his filtering time that is closely fool-proof. For instance, if on working according to the graduate he finds that the cake built up is not in accordance with his expectation, he can quickly examine



Courtesy The Dorr Company

FIG. 133.—Dorr Thickeners—Disposing of Trade Wastes

In tanneries and similar plants recovering the waste products has been difficult, but now the advantages of the Dorr Thickener are reawakening interest and its installation relieves the factory management of one more worry.

his filter cloth and make sure of its porosity, and if it is all right he can rest assured that his material is not of the same cake-forming properties.

Versatility of Filter.—One of the greatest weaknesses in the modern filter has been its distinct application. For the majority of installations, each machine has been specially designed for the work in hand. After the initial operation of the filter a change in the chemical process may occur, with consequent change in the character of the liquor being filtered. That filter sufficiently versatile to take care of this variation is the most practical filter. Often the specially designed machine is, however, more versatile than is considered practical.

In the pressure leaf filters, the versatility lies in the spacing of the filter leaves. This is a matter of initial design when more outlet openings are provided than are necessary for the material on which it is to be applied. For instance, when leaves are required on 4 in., 6 in., or 8 in. centers, a press drilled for leaves on 2 in. centers is ready to accommodate any one of these spacings. Pressure filters of more recent manufacture have this feature, most necessary if the installed machine is to have any versatility.

On plate and frame presses the versatility most resorted to is to run off the last of a batch, which, being less than the amount required to fill a full press, requires a smaller press. A blank plate can be inserted for any standard plate and shorten the press at will.

On continuous filters the first means of meeting a variation in the character of the product is to change the rotative speed. This is necessary for both more rapid and slower filtration. It is also possible to change the liquor level and consequently the submergence of the filter. This change is practical only for freer filtering and constant washing time. Probably the most effective means of maintaining production with a change to a slower filtration is to better thicken the slurry being fed to the filter. This increases the duty of the filter in respect to the solids, which are the determining factor when the sludge becomes a slower filtering product. Coincident with thickening the slurry, raising the temperature so as to decrease the surface tension of the liquid is the combination most likely to enable the filter to maintain production in spite of the change in the material.

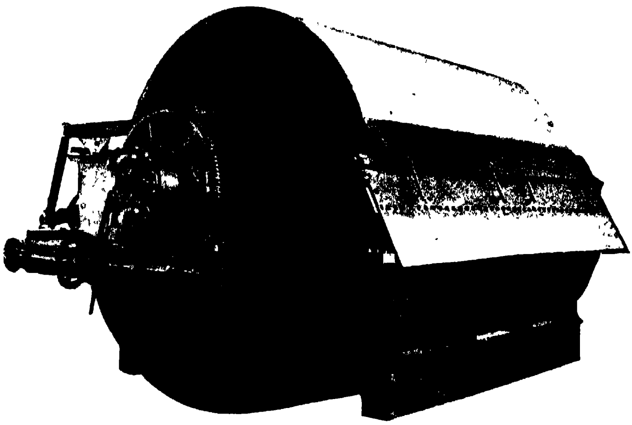
Versatility in the filter is often not necessary in plant practice. It is a positive asset, however, when new processes are tried out or when a mined raw product is used in the manufacture of the material. In the former case, short cuts are likely to be discovered and the filtering characteristics changed. In the case of raw mined products the content of gangue, or other undesirable, will change, requiring either a judicious mixing of good and baser ores or the changes in filter operation as referred to above.

The ease of converting the continuous filter to meet changing conditions is an advantage often overlooked but none the less real.

Continuous Operations.—Every plant would like to have its processes and machinery work continuously. It is impractical to work some processes requiring varying time for complete reaction, continuously. It

is likewise impractical in many instances to apply continuous filters on some hot or corrosive liquors which are prepared by continuous processes. There is, therefore, a proper layout that will allow an intermittent process and continuous filters, or vice versa, to operate efficiently.

In brief this situation is taken care of by proper reservoir capacity. In an intermittent process this reservoir is a tank from which the liquor is fed to a continuous filter. A similar tank with agitator takes care of a continuous process with an intermittent filter. This is likewise the case when the filtrate is evaporated to a higher density. When the solids are



Courtesy Oliver Continuous Filter Company

FIG. 134.—Oliver Filter—High Submergence Type.

The maximum submergence of the drum represents the maximum filtering efficiency. Only where washing or drying singly or together can be minimized is high submergence practical. When the product requires agitation it is interesting to note the mechanics of the rocker arm which readily suggests the walking beam of the old-time ferry boat.

dried or disposed as a transportably dry cake in wagon or carloads an intermediate storage hopper acts as a reservoir in taking care of a continuous discharge of solids or an intermittent discharge to a continuous dryer.

In this connection, the uniform satisfaction obtained with Dorr Thickeners as storage reservoirs of such slurries is well worth noting. By lifting the rakes overnight production can be stored for dewatering on the day shift. It simply means that the rakes are dropped in the morning and raised at night. This feature has been further expanded to become a blending tank, when a uniform product is required, the preceding processes to the thickener delivering batches of variable material. The unloading of the solids by the Dorr rakes is uniform and if the slurry becomes too thick for free pumping sufficient liquid is always easily added.

Repairs, Renewals, Etc.—Production is the chief concern of any manufacturing plant. Efficient production is the goal of every progressive manufacturer. In reality there is no difference between getting out the product and manufacturing it economically. An economical production means both continuous and maximum output.

Shut down of machinery is the surest method of halting manufacture. Conditions resulting in shut downs are not precipitated quickly, they are the accumulative effect of faulty conditions. The existence of faulty conditions immediately lessens the economy of production. Surely constant and economical production are synonymous.

Filter cloth renewals occasion more shut down of filters than any other cause. Renewals may be necessary by reason of defective cloth, by clogging up of the cloth or by reaching the life of the cloth.

Defective cloths in most leaf filters are impossible for more than one day in a well operated plant. Two or more spare leaves ready for immediate replacement should always be on hand. The time required to change a leaf should never be sufficient to warrant postponing the substitution of a new leaf for the defective.

A cloth that becomes impervious is either a cloth in which crystallization has taken place or in which fine solids of suspension are imbedded. It is assumed that the discharge is complete, within the limits of the method employed. Such lack of porosity is cumulative in effect. If the clogging action starts at any point more filtrate must permeate the rest of the cloth. Increasing the flow increases the opportunity for greater crystallization or more trapping of fine particles.

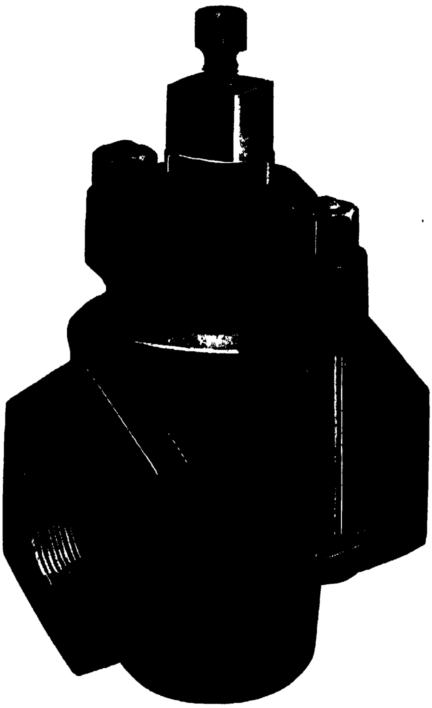
The main question in renewing blocked cloths is when to do so. This is in no small measure dependent upon the ease with which it can be done. Filter press cloths are the easiest to renew, Sweetland leaves are quickly changed, the cloth on continuous drum filters is quickly changed if proper provisions are made to rotate the filter quickly when putting on the spiral wire winding. If, then, these changes can be made quickly they should be made often and long before the filter capacity has fallen 33⅓ per cent from normal. If this limit is reached at the end of a week's run or at the end of one day's run, the replacement should be made at that time.

Auxiliaries.—The industrial filter is not a self-contained unit. Its operation is dependent on the proper functioning of its auxiliaries. These include feed pumps, air compressors, the motors or jack shaft drives for them, the piping, valves, etc., that make up the accessory equipment to filter presses and pressure leaf filters. The vacuum pumps, filtrate exhausters from vacuum receivers as required in the operation of suction machines are likewise included under this heading.

The dependability, the proper functioning and maintenance of these auxiliaries is a great part of filter operation. Dependability must enter as a prime requisite of each and every pump, motor and other auxiliary. The purchasing department must view competitive units from this angle first, and price, etc., secondary. In the plant the unit must be installed so as to be positive in operation. Long suction lines to pumps, wet

locations for motors, bearings inaccessible for lubrication are outstanding examples of the wrong way to install for dependable operation.

Proper functioning of accessory equipment is assured when the duty required is well within the range of the unit. Handling thick slurries with nicely designed centrifugal pumps is not a duty well within the range of



Courtesy The Merrill Company

FIG. 135.—Merco Cock.

The exterior appearance of this most useful piece of equipment will seem but slightly different from the conventional cone plug cock. Its operation, with its freedom from sticking and leaking, is in much greater contrast to the old-time models.

such units. To use a motor with a horse power rating equalling the horse power input is generally considered good engineering, but this is not so in filter work; because the duty of the pump for filter work is too variable. To have a motor running at full load, or slight overload, is too close to the failing point of the motor, for should a piece of bagging gets into the pump and momentarily raise the input horse power, the added

load burns out the motor. Vacuum pumps too close to the average requirement are likewise not well within the range of necessary duty.

Proper functioning of auxiliaries requires accessibility of the units. Pipe lines should be fitted with plugs and crosses instead of elbows; unions should be used extensively so that any line can be readily broken down if it crystallizes or in any other manner becomes clogged. Stuffing boxes should be easy to repack, flanges on removable heads of pumps easy to take off, shutoff cocks placed so that the stem of plug or valve can be quickly removed to be cleaned or replaced. A little foresight, just a little common sense, is the answer to the proper functioning of auxiliaries to the filter.

Maintenance of accessory equipment would seem to be a part of the requirements of the proper functioning of the units. However, in chemical plant practice corrosion of the equipment increases the importance of maintenance. Proper maintenance is best expressed as "Renewals well within the life of the equipment."

Corrosion is the dissolving of metal or material in contact with the liquor. This is true irrespective of the unfortunate experience so often occurring where a metal has been tested in a liquor, found satisfactory and when put into the operation of the filter fails unexpectedly early. Such failures are proof of inadequate tests. First there is always some erosion in the handling of the filter slurries. This accounts for some of the discrepancy, as the erosion prevents a coating building up on the surface to act as a protector. In consequence, fresh surfaces are presented for successive corrosive attack. And again impurities exist which act first as poles for local electrolysis intensifying the corrosion or as catalysis also increasing the rate of corrosion. Absorptive materials like decolorizing carbons are insidious in eating up pipes and valves due to the combined action of their erosive and catalytic corrosive tendencies.

To renew any wearing part well within its life presumes previous experience. Packing, gaskets, impellers, etc., are the usual replacements most often required. To postpone renewing them until the machine breaks down completely is positively faulty maintenance. The interruption of production from such causes invariably occurs when it hurts most. To operate at a decreased efficiency, as must always result when accessory equipment is under par, is a further loss often lost sight of. To clean up after a break down is time wasted but whenever a gasket blows, if an operator has not been blinded, scalded or worse, the plant must consider itself lucky. The operation of a filter should always contemplate time out per shift, or per day, or at each week end for renewals of wearing parts. Continuous twenty-four hours' operation should be obtained in twenty-one or less hours of filter operation thus giving plenty of time for repairs or renewals.

Proper maintenance is possible only when renewable parts are in storeroom or kept convenient to filter station. Every accessory installed should have replaceable parts purchased with it and always be kept on hand. It is poor control to be caught with a breakdown and have no replaceable on hand.

Maintenance figures as a necessity of uniform production. Where renewals are often and of major moment substitute units, convertible and multiple units insure against complete cessation of production. Local conditions will dictate to what extent such arrangements are needed.

It is unfortunate that obvious common sense precautions are insurances against faulty maintenance. Being so, they are too quickly overlooked and the filter operation weakened by such oversight. There is nothing extraordinary in good maintenance of filter equipment, only a proper appreciation of the work to be accomplished with a realization of the wear to be expected.

Interdepartment Co-operation.—It has been said that a company is as good as its organization. Certainly a plant is as good as the team work of the various departments. In possibly none of the factory stations is there more necessity or bigger opportunity for this co-operation of the two departments—chemical and engineering—than in the filter station.

Many plants have suffered from friction between these two departments. In the majority of instances analyzed, the trouble has been traceable to professional jealousies. No chemist and no engineer is so well informed as to be all sufficient. Each needs the best the other has to give and petty jealousies belong to undergraduate days, not to plant practice. The jealousies are not always apparent but in every case frank and full discussion of just what is desired and how near it can be approached is too often missing. It is one thing to work a process beautifully in beakers in the laboratory and different to make it work in the plant. Materials of construction, methods of agitation, feeding the liquors, maintaining temperature, etc., are the engineer's problems only after complete advice and the co-operation of the chemist.

It is simple to co-operate when the plant is working smoothly in every day routine. When trouble occurs the two departments should seek to take the blame and assure themselves their end of the problem has full investigation. If each tries to lay the blame on the other the true source of the trouble will eventually come to light and the real correction of the trouble be delayed. So many times the engineers have been blamed for a pump failing to give a desired pressure and after overhauling the pump the increased pressure produces no more filtrate. The chemical department later finds that a reagent has been used of lower strength and the precipitate changed to a more contrary solid. If both branches make their own investigations co-operatively and simultaneously the troubles are soon located and the plant is soon operating smoothly again.

Cordial relationship between the various departments is significant. When these obtain, problems are opportunities, not disturbances. Overcoming difficulties increases the morale and the plant produces results, let come what will. Happily this condition does exist in many American factories and is more the rule than the exception. It is necessary and should be fostered.

Filter Progress.—The advance made in American Industrial Filtration is a combination of necessity in reducing labor charges and an atti-

tude of constant criticism. The latter has been sufficiently constructive to be a pertinent factor in the progress.

Such criticism is entirely too localized both for the best plant results and for the continued advance of this branch of Chemical Engineering. Plant superintendents, chief engineers, and process foremen cannot afford to be content with present operation or to postpone indefinitely betterments they know ought to be installed. This attitude of constructively criticizing filter results should be part of the stock-in-trade of every filter manufacturer, but such criticism is expected and required in the competition for business.

The factor of plant men's criticism is tremendous and will increase if this attitude can be instilled as a habit throughout all the plants in the country. The greater the criticism the greater the knowledge of the principles of filtration and the less number of misapplications. The more minds seeking to make filtering machines better the surer our past progress will continue.

When the plant operators seek to better their filter performance each should remember that the mechanics of the filter is but a part of the problem. Rendering the material filtrable is the biggest factor and research and improvements on this phase of filtration abound in opportunities. More and more plant men realize this and present day efficiency is based largely on this awakening.

Much effort has been made to acquaint superintendents and managers of plants with the advantages and fine points of the different types of filters, but inadequate attention has been given to instructing the operators. The results, so often recorded, of machines starting with capacities far in excess of requirements and a month later lacking capacity are due, time and again, to inefficient operation traceable to ignorance on the part of the operator. Superintendents should know the "tricks of the trade" in order to exercise intelligent control, but the operator should be the plant's expert on the particular material being handled and it should not be left to him to learn by graduating from the school of experience. That is too costly. To instruct him is cheaper and not difficult even with foreign unskilled labor.

Along these lines it is gratifying to note that more and more concerns are taking up the slogan "Instruct the Operator," for he, in the last analysis, should be the filter expert in his department if the company is to have the most efficient plant.

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